SCIENCE FOR MODERN LIVING

USING MODERN SCIENCE

9

SMITH · JONES

Authorized text
1951
Grade IX

SCIENCE FOR MODERN LIVING

USING MODERN SCIENCE

9

SCIENCE FOR

VICTOR C. SMITH

W. E. JONES

In Consultation With

W. R. TEETERS

J. B. LIPPINCOTT COMPANY


MODERN LIVING
Using
Modern
Science
Chicago • Philadelphia • New York

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Using Modern Science is a completely new textbook based in part upon *Using Science* by Victor C. Smith and Gilbert H. Trafton.

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Preface

The *Science for Modern Living Series* provides a complete general science program for grades seven, eight, and nine. It develops for the pupil an understanding of his whole environment in terms of underlying scientific principles and of their functional applications to problems of everyday living. In organization the texts provide for utilizing children's interests to stimulate learning and to solve problems by use of the scientific method.

The content. The amount of subject matter in this series of textbooks is greater than the average amount found in other junior high school science series. The interesting style, the carefully selected vocabulary, the definition of new terms as they are used, and the soundly graded experiences make possible the use of adequate informational material in the science program.

Content has been selected according to several criteria: (1) the continuing *study of syllabi* and courses of study; (2) an analysis of *current changes in the world* resulting from scientific developments; (3) an analysis of *needs, maturity levels,* and *interests of junior high school age pupils;* (4) practical *testing of new materials in classroom situations.*

The informational material is *scientific* and *functional.* While it appeals to children because of its inherently interesting nature, the text is not intended to stimulate superficial interests nor unfounded beliefs in interpreting the world of the child. Every effort has been made to develop sound scientific attitudes by example and by providing information and experience needed for scientific thinking.

The organization of the books. Each book consists of six units. Each unit is comprehensive and based upon some socially functional area of the large field of science. Each unit is introduced by an interesting pupil experiment.

Each unit consists of one or

two chapters. The chapter is introduced by a brief discussion which serves to lead the pupils and teacher into planning cooperatively a number of listed and described experiments, activities, demonstrations, and pupil reports. *Pupil-teacher planning and pupil activity are encouraged,* but the success of the following material of the chapter does not depend upon such activity.

Each chapter is divided into a number of problems. *Each problem is planned to serve as a day's program of work.* Text, self-testing exercises, and suitable teacher or pupil demonstrations make up the problem. The self-tests are of properly graded difficulty and require real study on the part of the pupil. Pupils may check their own self-tests. The teacher can assign a daily problem with confidence that the pupil will understand what to do, will be interested in carrying out the assignment, and will have means of measuring his own success in learning.

The text of each problem is continuous. That is, it is not broken up by irrelevant exercises, demonstrations, or experiments which the pupil cannot do at the moment. It does not include interpolated material which confuses the pupil. In schools where no activity or demonstration program is possible, *these texts have proved their usefulness as science readers* because of this sound organization.

Each chapter has abundant summarizing and review activities. The brief *review* of fundamental concepts and the *word list* for study emphasize major ideas of the chapter. The *exercise in thinking* is a matching exercise of *principles* and related ideas. It reviews important ideas while at the same time providing experience in seeing relations. It is useful as a pupil self-test or as a class exercise in understanding the fundamental principles derived from study of the chapter. These exercises in thinking constitute a major advance in providing means for developing an *understanding of scientific principles,* and of emphasizing understanding as a goal of learning.

If it is desired, the exercise in thinking may be administered as a test of ability to apply scientific generalizations to specific problems. Used in this way, it constitutes one of the few *valid and reliable tests of reasoning* available in the entire field of science instruction.

Both the recommended *motion pictures* and *filmstrips* and the lists of *reference books* have been carefully selected from the tremendous number available. Every film has been classroom tested and has definite value in contributing to understanding the major problems of the chapter.

The illustrations. The illustrations serve three major instructional uses. Arousing *interest* is one of these. Teaching an *understanding of details or processes* is accomplished by use of line drawings. Supplementing

and *enlarging pupil experience* is the function of most of the photographs and of many of the drawings. Many textbooks have used illustrations as a substitute for adequate text and to pad out an inadequate presentation of text material. The illustrations in this book are pertinent and to the point. Many have been obtained from industrial sources to help make science functional in a technological civilization. Others serve chiefly to direct pupil activity.

The grade placement of subject matter. A constant problem in science education is to meet the needs of pupils in terms of their maturity levels and interests, and still avoid repetition. The authors of this series have attacked this problem by extensive research involving use of objective tests to discover on what grade level the average pupil achieves a degree of mastery required to continue learning. Detailed analysis of subject matter in terms of its difficulty has made possible a sufficiently accurate grading of material to meet usual classroom needs. Thus these texts are graded on the basis of scientific measurement.

Selection of units in which to utilize detailed information has been made after careful study of child growth, syllabi, and testing materials in classroom use. Units proceed from grade to grade on the basis of complexity of underlying concepts as well as in terms of the child's maturing interests.

A complete learning program. This series of science textbooks embodies the best of tried and accepted science instructional materials and methods. The activities, self-tests, mastery tests, word lists, principles lists, visual aids, extensive references, demonstrations and experiments, and abundant functional textual material and illustrations provide a complete science program for grades seven, eight, and nine. The series is sufficient in scope to challenge the most progressive and complete city school, or it can be adapted to the needs of the meagerly equipped one-teacher school. The careful organization of reading, self-tests, and pupil activities makes possible *a minimum of teacher direction* when time and materials are limited. *This science program requires no workbook.* It is complete in the texts and teacher's manual.

The authors believe that the teacher does his most rewarding and useful work in his daily guidance of and contact with his pupils and have produced a program which will leave a major portion of the teacher's time available for actual teaching. The teacher using this series will be able to eliminate much time-consuming planning, correction of exercises, hunting for materials, working out of assignments, and other routine drudgery.

He will have the satisfaction of observing his pupils growing up, not only in general maturity but in understanding of themselves, their complex environment, and

the methods and techniques of scientific learning.

The acknowledgments. The authors are deeply indebted in many ways to their teacher friends and fellow workers. Many teachers have co-operated in giving objective tests on which grade placement of units is based. Many teachers who used the preceding *Science in Modern Life Series* have made suggestions of great value in producing this entirely new series. Many pupils have taken tests, contributed original ideas, and assisted in trying out materials in science classes. Pupils of the Ramsey Junior High School photography classes have assisted in taking pictures and by serving as models in the science activities illustrations. Many leaders in the fields of general education, science education, and curriculum construction have contributed to the basic philosophy and to the techniques on which this series of books is based.

The lists of reference books were prepared by Miss Katherine Putnam, Librarian, Bryant Junior High School, Minneapolis. The lists of films were prepared in consultation with Mr. E. Dudley Parsons, Consultant in Visual Education, Minneapolis Public Schools. The authors and publishers make special acknowledgment to the late Gilbert H. Trafton, pioneer in the field of functional science education.

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UNIT SIX: CONSERVING LIVING RESOURCES

Man has reached the moon by radar.→

SCIENCE FOR MODERN LIVING

USING MODERN SCIENCE

Introduction

1. What is science?

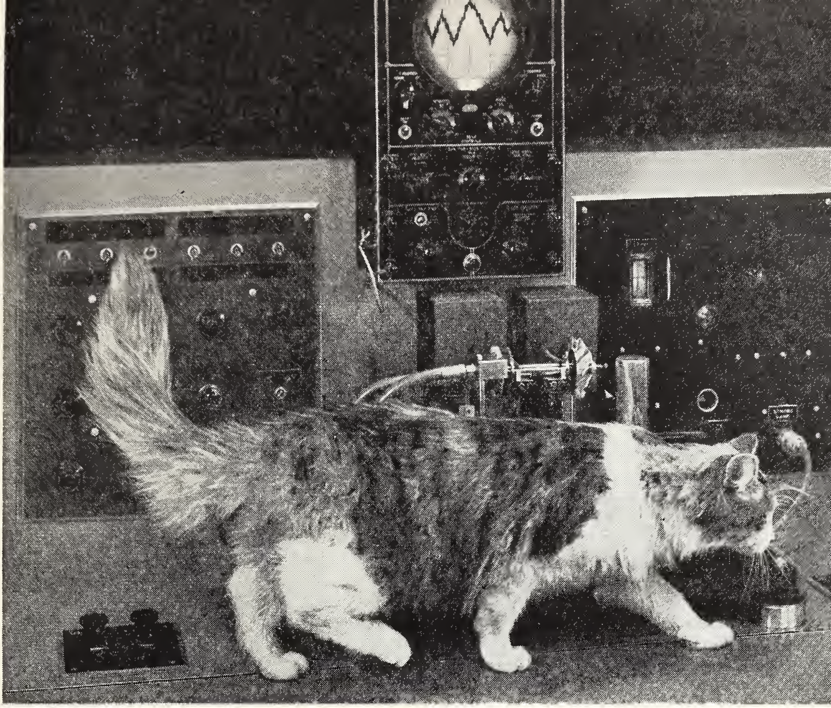
What do you think of when you hear the word *science?* Do you think of pouring some stuff from one bottle to another to make something fizz or pop or change color? Do you think of airplanes riding the stratosphere at a thousand miles an hour? Do you think of the struggles of early scientists to get men to believe in their senses and their sense instead of their imaginations? Do you think of all the useful things which make modern civilization possible? Or do you think of yourself becoming a scientist and working in a laboratory to improve the welfare of the human race?

Whichever of these thoughts you may have is sound and reasonable. For science is made up of many things. It is information, experiment, thinking, history, and the hope of the future. It is the way to health and freedom if it is properly used.

In its broadest sense, science is a way of thinking and doing things. But only people can determine why they do things. If they wish to help one another and live in peace, science is a tool useful for that purpose. But if they want to destroy each other, to waste their lands, to bring misery upon the human race, science can be used for that purpose, too.

What the right goals and attitudes are to be must be determined by each individual and each social group. Study of science should help you to develop some of them—respect for truth, habits of honesty, fair-mindedness, and a desire to think instead of to act upon impulse. Let us determine that science shall be used for the good of all.

How did science begin? If you remember the year 1600 as the beginning date of science, you will not be far wrong. It was about this time that Galileo and others of his time were making the simple beginnings of science.



Air Research Manufacturing Company

How would you measure the footfall of a cat? On the screen in the background an electrical instrument shows the pattern of vibrations caused by the cat walking on a steel plate.

When scientists first started their work they were greatly handicapped in several ways. The first handicap was that they had no sound method of attacking problems. Each problem was approached with a try-and-fail-and-try-again attitude. Next was the lack of any large body of tested and proved information. People did not know such simple things as the amount of pressure of the air, the speed that sound travels, nor that blood circulates. And the third great handicap to sound learning was lack of proper instruments, machines, and tools to carry on experiments.

In 1600 people had simple lift or suction pumps, such as are used today on some farms and at rural cottages. They had about the same arrangement of piston and cylinder and valves as do today's pumps. The users of these pumps knew that they would not lift water more than 15 to 20 feet. They did not know why water would rise in a lift pump. They used the explanation, "Nature abhors [hates very much] a vacuum." They did not know what

Nature was, nor why at a height of more than 20 feet it no longer abhorred vacuums.

A young scientist named Torricelli had been trained by Galileo. He undertook the problem of finding out why pumps worked as they did. Galileo had already made a water barometer, in which air pressure held water in a tube at a height of almost 34 feet. By careful experiments and reasoning, Torricelli was able to show that the lift pumps raise water because of air pressure. Their failure to lift water more than about 20 feet depended upon the amount of pressure of the air and upon the poor construction of the pumps. These pumps had leaky valves.

By a long series of experiments such as this a large amount of information was gradually developed.

What is science? Today science has become the most important single field of human knowledge. There are many who believe it is almost the only field of real knowledge. Science consists of three parts, equally important in understanding our environment and the activities of matter and energy. The first of these is the method by which scientists work. This method depends upon use of experiment and observation to solve problems. The second is the method of thinking by which a scientist arrives at conclusions. And the third is the information which has been discovered, tested, and organized according to the scientific method of learning and of thinking.

What are the chief branches of science? One great branch of science is called physics—the study of physical changes of matter. Physics is a tremendous field of science—in fact all science is physics. Many life processes are physical changes. Because physics is so broad a science, it is further divided for convenience into studies of machines, heat, light, matter, sound, and electricity.

Another great field of science is chemistry. Chemistry is the study of the changes which take place in the make-up of matter.

Chemistry overlaps physics, and one may study in universities the field of physical chemistry. In fact physics and chemistry are so often involved in the same changes at the same time that they are separated for study only for the sake of convenience.

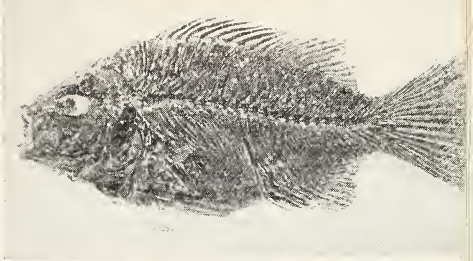
A third great field of knowledge is biology. The prefix "bio" comes from the Greek word *bios,* meaning life. The two sciences related to biology are botany, the study of plants, and zoology, the study of animals. Each of these sciences is further divided into sciences of classifying living things, of studying their structure, of studying their habits, and many other fields of knowledge. Biology overlaps chemistry and physics, for all life processes are chemical and physical changes.

The science of the earth is called geology. Geology is chiefly a study of the crust of the earth and its history. To know the history of the earth, it is necessary to

know biology, for the age of the rocks is determined in part by the types of fossil plants and animals found in them. The age of rocks is also determined by study of the elements from which they are made, and particularly by study of radium and related chemicals. This study is both physics and chemistry.

Another field of science is astronomy—the study of all the bodies in space. Astronomy is a branch of physics, for the stars are studied either by observing their motions or by studying their light, both of which are problems of physics.

All sciences finally depend upon mathematics for a means of expressing in an exact way what is learned by observation and experiment.



The bones of this fossil fish were found in a ball of dried clay. To understand how the fish was so well preserved and to know what kind of fish it was, requires an understanding of geology and biology.

Exercise

Complete these sentences:

Science is a means of learning by —1— and —2—, a method of —3— according to certain rules, and a large body of organized —4—. The science of the earth is —5—. Machines and sound are studied in the science of —6—. Changes in the make-up of matter are studied in —7—. —8— is the study of stars and bodies in space. —9— is study of living things. "Nature abhors a vacuum" because air exerts —10—.

2. What is the scientific method?

Everybody conducts experiments. When you shine one shoe first to see how much better it looks than the unshined one, you have performed an experiment of a simple kind. From experience you know that shining a shoe makes it look better, but you want to know how much better.

What are the six steps of scientific learning? A scientist performs his experiments in a more systematic way than you do when you shine your shoes one at a time. There are six steps through which every scientific experiment must pass in order for the conclusion to be accepted as true. These are:

1. Finding and stating a problem
2. Gathering information to solve it
3. Developing a hypothesis [hī·pŏth′ê·sĭs]
4. Testing the hypothesis by experiment
5. Drawing a conclusion
6. Testing the conclusion by experiment

A problem is a question which you feel must be answered. Mere idle curiosity about something is not a problem. It must be worthy of time and effort. One cannot have a problem unless he already knows something about a subject. If one knows enough about a problem to state it clearly, he has a much better chance of solving it.

People gather information in many ways. The first information is usually recalled by remembering what is already known about a problem. Then reading, discussion with other people, and observation are used to gain additional information.

Forming a hypothesis is necessary to make an experiment possible. Sometimes people say, "I have a hunch it will work this way." A hypothesis is an intelligent guess as to what the answer to the problem will be. Torricelli must have known something about air pressure in order to test the working of lift pumps.

What is an experiment? The setting up of an experiment is often difficult. We can approach our problem in one of several ways. We may arrange to produce some kind of change, and we observe how much something is different after a change than before. Many chemistry experiments depend upon this method. We add vinegar to soda. Bubbles are given off. We add more vinegar, but no more bubbles appear. Some change has taken place in the soda. Often we keep some part of the material for comparison. In the case of shining shoes, the unshined shoe served to show how much change shining produces. Something we keep in an experiment for the sake of comparison is called a control.

Sometimes we measure the change in known units. If heating a pound of water over a candle for five minutes produces a certain change of temperature, we have used three measuring units to describe the change in the location of the heat, from candle to water.

Often changes are so great that they can be readily observed. When a chemical changes color, we can see it easily. When one gas burns with an explosion, while another gas puts out a flame, we can easily note these changes.

Drawing a conclusion is perhaps the most difficult of all the parts of the scientific method. The early Greek scientists who said that Nature abhors a vacuum had observed the working of a pump, but had not drawn the right conclusion. They did not have enough evidence, and they did not follow good rules of thinking.

One error lay in naming something that was not proved to exist, and then acting as if it did. "Nature" is not a force, a person, or a thing. It does not think, act, or produce changes. A name does not necessarily stand for anything that really exists. The existence of many things can be demonstrated only by careful experiment.

When it is known what forces do exist, and what changes or conditions result from the experiment, then a conclusion is possible. Certain of these forces are called causes, and the changes or conditions they produce are called effects. The cause or causes must come before the effect, and under similar conditions must always produce the same effect.

Most things we know today have been tested by many scientists, and will be tested again. When knowledge is newly developed, we must not accept it as being true until many tests have been made. "Jumping at conclusions" is one of the worst of human failings, when thinking is required. Many people, if they do not know a sound answer to a problem based upon observation or experiment, will invent an answer and act as if the answer were true. A guess is of use only in forming a hypothesis—an idea yet to be tested. A hypothesis certainly should not be accepted as true.

When a conclusion seems to be sound, and is based upon considerable information or evidence, we call such a conclusion a theory. We have theories as to how life started upon the earth and upon the nature of matter. A theory may be accepted as true so long as the idea works satisfactorily in actual use.

When an idea has been tested so often, and results measured so accurately, that every careful scientist obtains the same result, and when no exceptions to the idea can be found, then the idea or general statement of the fact is called a law. A law in science is a summary of something we know.

Bausch and Lomb Optical Company

Experimentation is not new, for we see here a picture of the scientist Alhazen showing—almost a thousand years ago—that a stick thrust into water appears to be bent.

DEMONSTRATION: IS AIR COMPRESSED IN A BALLOON?

What to use: Balloon, glass tube, measuring cup or graduated cylinder, jar or tank larger than inflated balloon, rubber band, tape or marking pencil.

What to do: Inflate the balloon. Fill the jar with enough water that the balloon can be submerged in it without overflowing. Mark the level of the water in the jar. Push the balloon into the water until it is completely covered, and mark the height to which the water rises. Remove the balloon, and add enough water to the jar to

Society for Visual Education, Inc.

The study of living things, whether they be tigers or bacteria, is the science of biology.

bring it up to the second mark. Keep a record of the amount used.

Attach the glass tube to the balloon. Fill the measure with water, and invert it in the jar. Let air pass from the balloon through the tube to the measure until it is filled. Let this air escape, and continue to measure the air in the balloon until all is removed.

What was observed: How many measures of water were required to fill the jar to the second mark? How many measures of air were in the balloon?

What was learned: How many times was the air in the balloon compressed? (Divide the second number obtained by the first.) Was the balloon the same size in air as in water? How many other errors were made in this experiment? How accurate was your measurement? Does the experiment answer the question approximately or exactly?

Exercise

Complete these sentences:

A general statement of known facts is a —1—. A conclusion or idea which has been fairly well tested is a —2—. A working idea or guess to be tested is a —3—. Part of the materials of an experiment kept for comparison is a —4—. Forces producing changes are called —5—. The resulting conditions are called —6—. The six steps of scientific learning are: stating a —7—, gathering —8—, forming a —9—, setting up an —10—, forming a —11—, and —12— the conclusion.

3. How does science depend upon measurement?

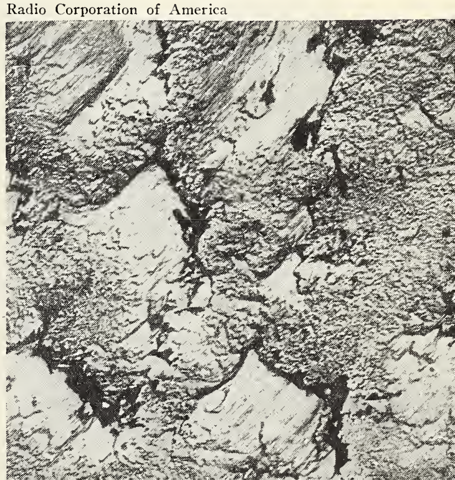
Have you ever thought of words as being vague and indefinite in meaning? For example, what does *green* mean to you? Is it the color of grass in the spring? Is it the color of pine tree's needles? If you do not believe that green is not really one color, but a large collection of colors, try to match a color of some green material with some other material so closely that a person with average vision cannot tell the difference.

Think next of the word *foot* as part of an animal. What kind of foot do you think of, a duck's, a horse's, or your own? What does a foot look like? How big is it?

Now think of *foot* as a unit of measuring distance. You know immediately how long a foot is. It is the distance between two

Do you think that the enamel of your teeth is perfectly smooth? This is how a tooth surface looks when magnified 45,000 time by the electron microscope.

Radio Corporation of America



Borg-Warner Corporation

By drawing a delicate diamond point across superpolished metal, this device measures roughness in millionths of an inch and shows the results on the dial.

marks on a standard ruler. If you compare several rulers, you may find as much as $\frac{1}{16}$ of an inch difference in the length of the foot on different rulers. But within very narrow limits we know how long a foot is. If we should use the most accurate measuring device known, we could measure within $\frac{2}{1,000,000}$ inch of a true foot of distance.

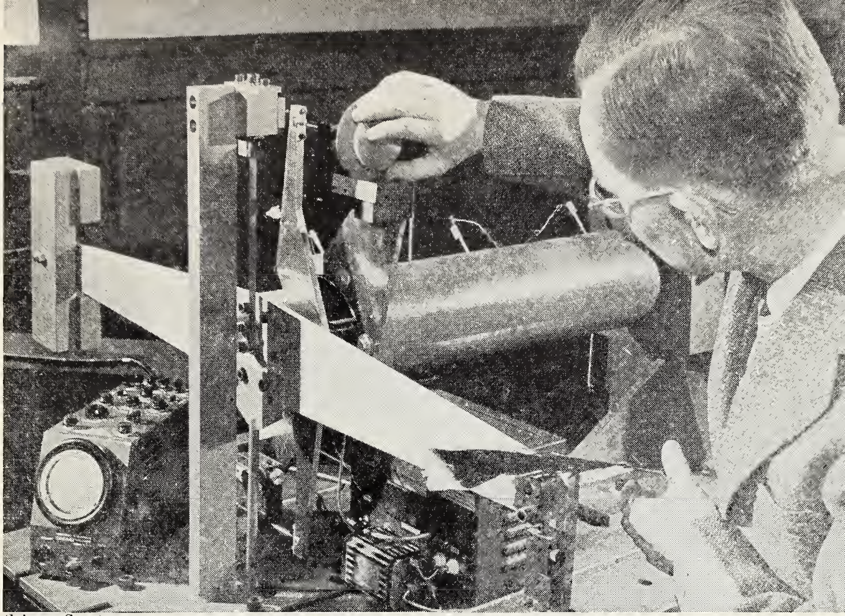
What is measurement? Measurement is a method of comparing something with a standard unit. We compare distances with the standard unit called a foot. The original unit is marked off on a bar of metal and kept in The Bureau of Standards in Washington, D. C. Or we may use other units, depending on the size of the article to be measured. These units may range in length from the unit used to measure the length of light waves to the unit used to measure space.

Common measuring devices are all around us. We use the clock to measure time. There is probably a thermometer on the wall, and perhaps you have a weather guide which measures humidity and air pressure. There often is a thermometer on the oven door. In the automobile are meters which tell you how much current the car is using or storing in the battery, how fast the automobile is going, how much gasoline is in the tank, and how hot the water is in the radiator. The grocer uses scales which generally have a stamp indicating that they are accurate enough for store use. Your gas or electric bill is determined from readings on a meter. You measure angles with a protractor.

When it is difficult to measure something directly, we still have indirect methods of measuring. Your science test is a measuring device, and the tests which accompany this book are fairly accurate measures of what you know if you take them honestly. They are more accurate than the readings on the average automobile gasoline gauge but considerably less accurate than the electric meter.

Measurement, then, consists of three parts. The first part is to decide upon a standard unit and mark it off or define it so that we know just what it is. The second part is to make devices to use in measuring in terms of the unit. The third part is making the actual comparison. The result is a number which has quite exact meaning.

Is measurement accurate? While measurement is much more accurate than any other kind of description, it still is not perfect. No one ever made a perfectly accurate measurement ex-



Science Service

This extremely sensitive twist detector indicates how much a steel bar is twisted by laying a feather on it.

cept by chance. But by having good instruments and using them carefully the amount of error can be reduced until it makes no practical difference. Scientists can now measure in millionths of an inch and billionths of a second.

Today it is possible to make the parts of a machine in several factories apart from each other. When the parts are assembled, they fit closely enough that the machine works well. A certain part of a machine may be exchanged for the same part of another machine of the same kind. Such fit depends upon quite accurate measurement.

When you use a ruler, you can increase your accuracy by turning the edge on which the scale is printed against the object measured. You can increase accuracy of weighing by keeping balances clean and by handling weights carefully in order not to damage the knife-edge on which the balance rests. You can read a thermometer or glass graduate more accurately by holding your eye level with the mark.

What are some practical units of measurement? In order for a unit of measurement to mean anything to us, we must become acquainted with it. You know, of course, that there are two systems of measurement commonly used in the United States, the English and the metric system. Neither is more acurate than the other, but the units of the metric system are much easier to use than are those of the English system. Because

Wood engraving by Lynd Ward, Oil Industry Information Committee

Modern explorers hunt for oil in the jungle by mapping formations which may later be explored by more exact measuring devices.

you are familiar with the English system, it is generally easier to learn the metric system in terms of the known system. The unit of measurement corresponding to the yard is the meter. Most laboratory rulers are meter sticks, which are a little more than a yard long. The centimeter is $\frac{1}{100}$ of a meter, and is about .4 inch. About $2\frac{1}{2}$ centimeters make an inch. A foot is about 30 centimeters.

The unit of weight is the gram. A kilogram which is 1000 grams weighs about 2.2 pounds. There are about 28 grams in an ounce, about 450 in a pound.

It is well to use the metric system until its units have meaning to you. Most of your science measurements should be made in the metric system. The following table gives you more exact information for comparing the two systems of measurement:

1 meter	= 39.37 inches
1 inch	= 2.54 centimeters
1 foot	= 30.48 centimeters
1 ounce	= 28.35 grams
1 pound	= 453.6 grams
1 kilogram	= 2.205 pounds
1 liter	= 1.06 liquid quarts

DEMONSTRATION: HOW DOES THE WEIGHT OF OIL COMPARE WITH THAT OF AN EQUAL VOLUME OF WATER?

What to use: Balance, weights, milk bottle or flask, sample of oil.

What to do: Weigh the bottle and make a record of its weight. Then fill the bottle with water to a certain definite level, and weigh the bottle and water. Record this weight. Empty the bottle and dry it, and fill it to the same level with the oil. Weigh it as before.

What was observed: To find the weight of the water and the oil, subtract the weight of the bottle.

What was learned: Which weighs more, oil or water? To obtain a more nearly exact answer, divide the weight of the oil by the weight of the water. The resulting number is called the specific gravity of the oil. Are you certain this answer is correct and would not be changed by repeating the experiment? Does your answer apply to all oils, or only to the sample tested? What is the sample? What hypothesis is tested?

Exercise

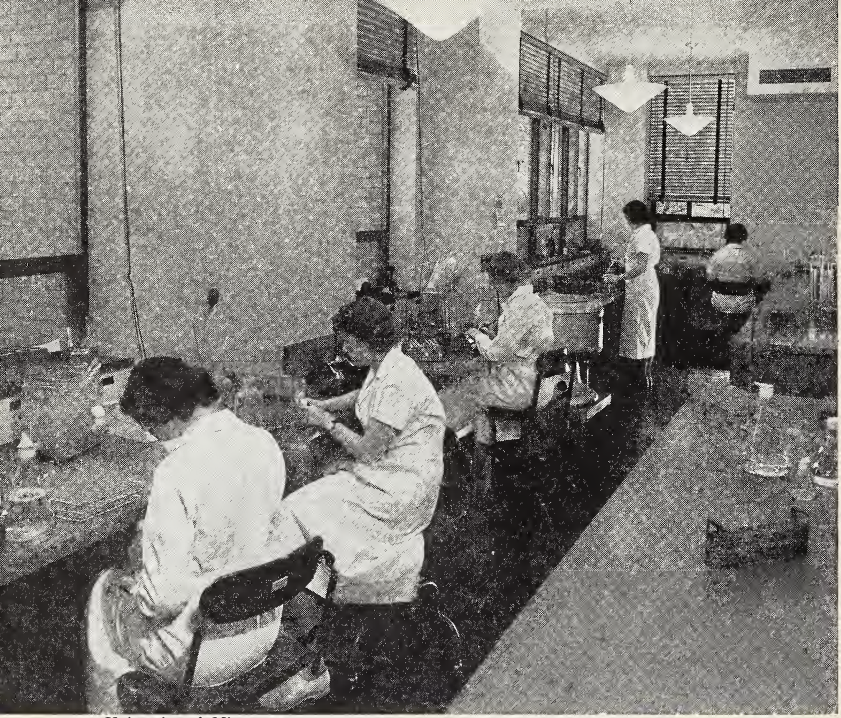
Make a table by ruling your paper into three columns. Head the columns as follows: MEASURING DEVICE, NAME OF UNIT, WHAT IS MEASURED. *Write in the names of at least 10 devices, and supply the necessary information to complete the table.*

4. How do scientific discoveries grow?

Today the cow in the farmer's barn does not switch her tail into the milk pail as she tries to shoo away the flies. One reason, of course, is that cows are milked by machine. But another and still more important reason is that in a modern barn there need be no flies.

In 1874 a chemical with the tongue-twisting name of dichloro diphenyl trichloroethane was produced by putting together other chemicals in a laboratory. So far as was known it had never existed in nature, and nobody knew whether it might have any use or not. Then during the war of the 1940's there arose great need to prevent such diseases as typhus, plague, and malaria, all of which are carried by insects. Among the thousands of chemicals tested to find one which would kill insects without being very poisonous to human beings was this same dichloro diphenyl trichloroethane. It was found that, by using this chemical properly, people living together in crowded and filthy conditions still need not be infested with lice. A little of this chemical powder dusted in the clothing would kill lice before they could do harm.

Today the American farmer regularly sprays his barn with this chemical—DDT—or a still better chemical in order to increase his income. For it has been found that dairy cows give 10 to 15 per cent more milk when they are not troubled by flies. The long story of this one chemical extending over a period of 70 or more years from the time of its discovery to its general use illustrates the relatively slow development of practical uses of science.



University of Minnesota

These women are making blood examinations. Many diseases can be detected by study of blood. Many states maintain laboratories such as this to help diagnose disease. You can see how important the scientific method is in this necessary work.

When did the modern age begin? It is generally agreed that the modern age of scientific living began with the industrial revolution, about 1800. At this time sufficient inventions had accumulated to make it possible for many people to have more things to use than they could make by hand at home. Shortly after this time transportation changed from animal to mechanical power with the completion of the first steam railroad.

But even so, the industrial revolution did not at first affect many people nor greatly change their way of living. People still carried water into their houses in pails, traveled in horse-drawn carriages, used kerosene lamps, heated their homes with stoves or fireplaces, and were in general dirty, unhealthy, overworked, and uncomfortable.

Let us consider briefly the age of some of the devices which we use as a matter of habit. The first practical typewriter was built in 1873. The telephone was invented by Bell in 1876, and the first practical electric lamp was developed in 1879. In the 1870's and 1880's Pasteur, Koch, and

Radio Corporation of America

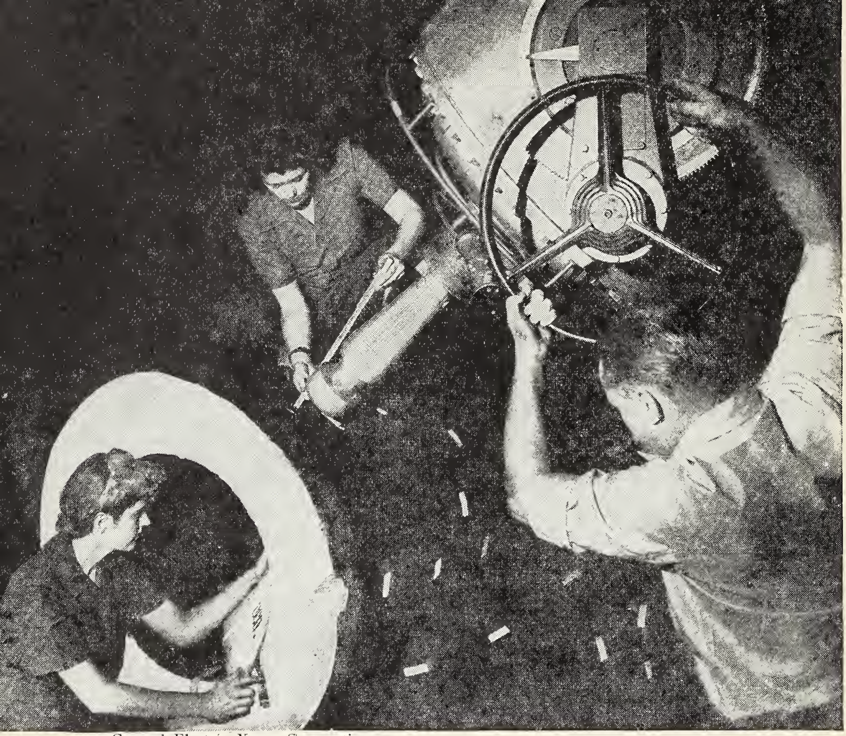
The electron microscope (*upper right*) makes pictures of bacteria so that they seem as large as terrier dogs. What is the advantage of such improved methods of observation?

Lister proved that some diseases are caused by bacteria.

In 1884 the linotype machine was invented to set type rapidly, and a fountain pen was invented which would work after a fashion. Four years later, 1888, the first portable roll-film camera was invented. It was not until the 1890's that automobiles began to appear. The first four-cylinder automobile was built in France in 1890, and in 1893 the first Ford car was built. Flight came just 10 years later, in 1903. Then the Wright brothers first got an airplane off the ground in sustained flight. Since that time radio has been developed, the first broadcast taking place in 1906. It was not until the 1930's that synthetic [sĭn·thĕt′ĭk, man made] drugs were developed.

These are examples of some of the important scientific discoveries or inventions. At the same time people were developing a taste for better living as bathtubs, canned foods, heating plants, improved fabrics, and other common things which were becoming available.

Every device which is accepted for common use goes through certain typical stages of development. Someone invents a new device because he is able effectively to use accumulated knowledge



General Electric X-ray Corporation

These people are using a million-volt X-ray unit to find out if there are flaws inside the heavy piece of steel. X-rays can pass through heavy metal and other nontransparent objects. Since we cannot see inside such materials directly, we must use other aids for observation.

and his own inventive skill. At first the device is usually crude and imperfect. People are slow to accept it as having value. After a period of testing and improvement, increasing numbers of people accept the device. This number is related to the amount of skill required to operate the device and to its cost. For example, relatively few people use a typewriter because skill in its use is attained only after several months of practice and, in addition, the machine is fairly expensive. In comparison the telephone can be used by almost anyone with little practice. Its wide use is further explained by the system of low monthly rental. About three years rental of a telephone equal the cost of a typewriter.

What is modern research [rė·sûrch′]? Science today has changed from the picture of the lonely inventor working in the woodshed perfecting a device while the neighbors look on in scorn. Today the modern inven-

tion is likely to be produced in laboratories of industrial scientists. Even if it is invented by an individual, it is generally developed by an industrial laboratory before it is placed on the market.

Scientists from several fields may work on one invention. In developing a jet turbine engine to replace the common gasoline engine, chemists had to develop new fuels and a lubricant which will withstand high speeds and temperatures. Other scientists had to develop metals which are strong and do not melt or burn in the engine. Engineers found the best design of the parts.

It has been found that each dollar spent in research returns about $100 in profits. As a result of much improved testing, products of today's laboratories are likely to work better than did early inventions. Research—the complex experimental method of modern science—can solve most problems of production of material things.

The next stage of scientific learning should be to try to find better ways for men to live together in comfort and security.

Exercise

Complete these sentences:

Modern methods of communication are about —1— years old. The chemical —2— was one of the first synthetic insect killers. The change from making things by hand to making them by machines is called the —3—. The machine which sets type is the —4—. Modern ideas about causes of disease developed about —5—. About —6— years later synthetic drugs were developed to kill bacteria. Modern complex experimentation is called —7—. Typhus and malaria are spread by —8—.

A review of the introduction

The scientific method of thinking develops through six stages. A problem arises. A search for information follows. A temporary conclusion or hypothesis is formed. The hypothesis is tested by controlled observation, by experiment, and by measurement. A conclusion is formed. The conclusion is tested in as many ways as possible.

A conclusion is called a theory until it is quite thoroughly tested. Then a general statement of known facts is expressed as a law.

Science is defined as organized knowledge. The law of cause and effect is used in organizing knowledge. Astronomy, biology, geology, physics, and chemistry are the chief branches of science. Science is quite dependent upon mathematics and systems of measurement. Increasing skill in the use of mathematics and measurement, and the accumulation of scientific knowledge, have enabled man to make much progress in developing practical devices and ideas.

Word list for study

physics	kilogram	meter	theory
geology	chemistry	liter	unit
hypothesis	astronomy	biology	centimeter
control	law	problem	research
measurement	conclusion		

An exercise in thinking

Write the numbers from 1 to 25 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. The best way to discover facts is by experiment or controlled observation.

B. The cause of a change or condition must come before the effect and must always produce the same effect under the same conditions.

C. A hypothesis is an idea to be tested by experiment and proved or disproved by evidence.

D. A theory is a reasonable explanation of observed facts.

E. A law or principle is a general statement of known facts.

F. Repeated testing of ideas is necessary to establish their truth.

G. A name does not necessarily stand for anything that really exists.

H. A superstition is an unfounded belief based upon fear, faulty observation, or confused cause and effect.

List of related ideas

1. Edison made hundreds of tests to find a satisfactory lamp filament.
2. Water underground can be located by use of a willow stick.
3. A birthmark is caused by the mother receiving a shock before the child is born.
4. Although a dairy claimed to sell extra-rich milk, tests showed its milk to be only average.
5. The so-called science of reading character from the shape of the skull was worked out by measuring a few people's skulls.
6. A four-leaf clover brings luck.
7. Although she was sure she had not been exposed, Mary had the measles.
8. All matter is made up of small particles called atoms.
9. Boils are a good sign because they purify the blood.
10. A cup fell from a shelf and broke without any apparent cause.
11. One man claims that his experiments show that people can transfer thought for a considerable distance.
12. All living things probably have common ancestors.

13. Doctors never find the mind when they operate.
14. The total amount of matter does not change when a fire burns fuel.
15. Those who say they can read character from handwriting cannot actually do so.
16. The earth was possibly formed from materials from the sun.
17. Nobody could agree just what is meant by beauty.
18. The children became excited while waiting for Santa Claus.
19. The food you eat today cannot make you sick yesterday.
20. We know that gravity operates all over the world.
21. The size of the universe is either increasing or remaining the same.
22. Only when he tested the rate at which objects fall could Galileo show that his idea was right.
23. Ghosts, fairies, and goblins exist only in the imagination.
24. Measurements to determine the speed of light have been made repeatedly by different methods.
25. Thieves are kind because a thief once gave his mother five dollars he had stolen.

Some things to explain

1. Explain this statement: The scientific method is the most important tool of civilized man.
2. As scientific discoveries are made, are further discoveries likely to be made more rapidly or more slowly? Explain.
3. Why are the words *perfect* and *exact* rarely used in carefully worded scientific reports?
4. Why should we be careful to know the difference between hypotheses, theories, and laws?
5. Could our many inventions have been developed without use of the scientific method? Explain.
6. Explain this statement: In a society ruled by ignorance, superstition, or dogma, the most intelligent people are likely to be the most ignorant, superstitious, or dogmatic.

Some good books to read

Bendick, J., *How Much and How Many*
Burlingame, R., *Inventors Behind the Inventor*
Compton's Pictured Encyclopedia
Hart, I. B., *Makers of Science*
Harvey-Gibson, R. J., *Two Thousand Years of Science*
Holmes, H. N., *Out of the Test Tube*
Jaffe, B., *Outposts of Science*
Pollock, P., *Careers in Science*

Our use of materials such as sulfur has made possible modern living.

UNIT ONE

CONSERVING MATERIAL RESOURCES

Alice placed a rather strange-looking piece of apparatus on the demonstration table. It looked somewhat like a volcanic mountain. She set it on a stand and adjusted a burner beneath it.

She smiled as she explained, "I am not going to produce either a volcanic explosion or an atomic-bomb explosion. But I am going to demonstrate my model volcano. I assure you that you will not feel any earthquakes, nor will you need to run for your lives."

She lighted the burner and rather quickly moved back a little way. At first nothing happened. Then all at once a cloud of smoke, filled with sparks, shot up from the top of the model mountain. It continued for a little while, and the smoke drifted into the room.

Alice said, "You can see readily how I made the mountain. It is built around a tin can that once contained soup. The base is a sheet of metal. The mountain itself is made of clay.

"The explosion was not really an explosion, for I purposely left the top of the can open. I did not want any damage to result from the demonstration. I mixed two chemicals together, potassium chlorate [pō·tăs′ĭ·*ŭ*m klō′rāt] and sugar. Sugar burns with a nice smoke. The potassium chlorate provided the large amount of oxygen needed to make the sugar burn rapidly. Now I'll burn a little of the same mixture in the open so that you can see how the burning takes place."

She poured about a spoonful of white crystals on a piece of metal and put it above the burner. It suddenly burst into flame with a violet color. When the burning stopped there was a heap of black material left on the metal.

Alice said, "The violet color came from potassium vapor in the flame. The black stuff is unburned carbon from the sugar."

CHAPTER

1

Matter from Atom to Universe

Suppose you try to answer a simple question. What is matter? You might say it is the stuff things are made of. That would be a right answer. But suppose you try to go further, and try to explain what matter is made of. That is more difficult. You may know some of the names of particles of matter. You may say it is made of atoms or molecules. Perhaps you have been reading about atomic energy in the newspapers and magazines, and know that energy can be taken directly from matter. It is likely, though, that you will soon find that you do not really know what matter is.

Scientists do not know all about matter, either. But they have been studying it for a long time. About the time of the Revolutionary War a Frenchman named Lavoisier found that matter can be changed chemically. He heated some mercury in a closed glass container for 12 days, and it gradually became covered with a red powder. After this time the mercury would no longer change. Lavoisier decided that the red powder was made of the mercury in combination with some material from the air. He removed the red powder, heated it, and collected the gas it gave off. You probably know already that it was oxygen. Since Lavoisier started the science of chemistry with this and other experiments, people have been studying matter all the time. Perhaps you are ready to learn some of the things that scientists know about matter.

Some activities to do

1. Does pressure affect the boiling point of water? Heat water in a flask until it boils. Let it boil long enough to drive out the air, and stopper it tightly. Cool the flask with a cold, wet sponge or with running water. Notice how long the water continues to boil. If a thermometer is available, take the temperature of the water as soon as it stops boiling. Test the temperature of

the flask with your hand after it has cooled somewhat.

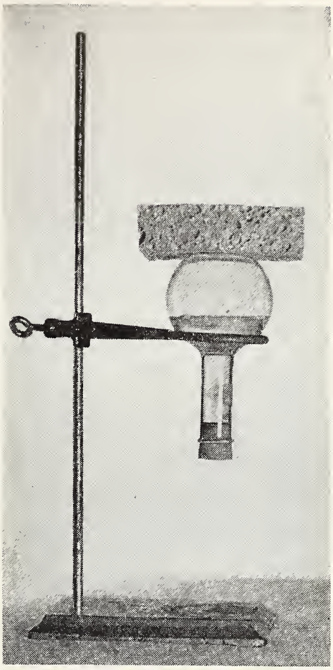
2. How does Galileo's thermometer work? Obtain a bottle, a one-hole stopper and a glass tube, and a water glass. Use a room thermometer for comparison. Arrange the equipment with the glass tube and stopper in the bottle, with the long end of the tube extending from the bottle. Place this bottle above the glass, with the end of the tube dipping into the glass. Put enough water into the glass to cover the end of the tube. Warm the upper bottle until several large bubbles of air come through the water. Then let the apparatus stand, noting the height of the water in the glass tube as the temperature changes.

3. How many stars can you see? Select a small area of the sky, marked off by bright stars. Count all the stars you can see in this area. If you can obtain a field glass, count the stars you can see with its help. How large a part of the sky do you think your counting includes?

4. The orbits of planets are not true circles, but ellipses. To draw an ellipse, obtain a string about a foot long. Tie it to form a loop. Push two tacks through your paper into a board. At first put the tacks two inches apart. Put the loop of string over both tacks. Then put your pencil point into the loop, pull it tight, and draw a curved line around the tacks. Move the tacks to make curves of different shapes. The earth's orbit is an ellipse. Can you explain why the distance from the sun varies?

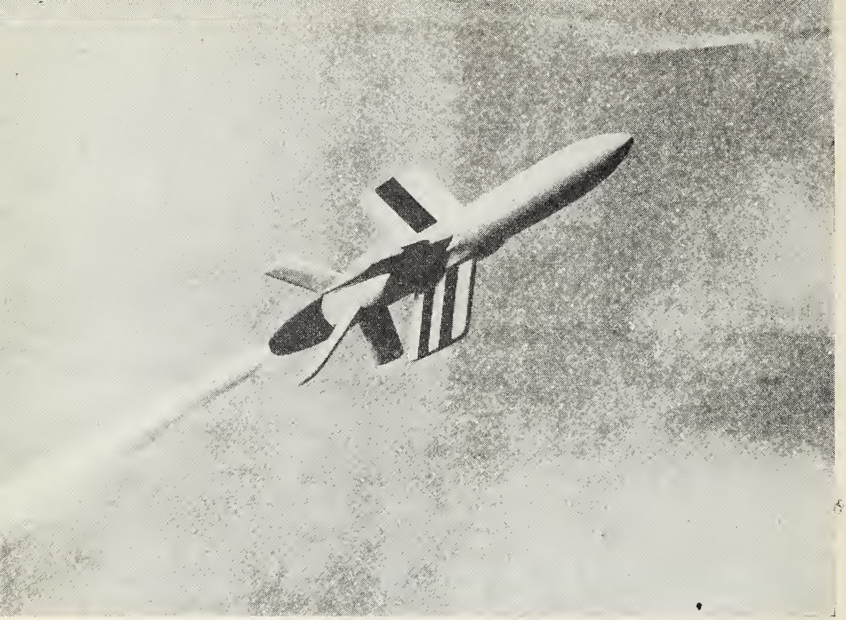
5. Continue enlarging your rock and mineral collection, or if you have none, start one.

6. How do siphons work? Find as many ways of making a siphon as you can, using reference books for ideas. A siphon can be made to produce a fountain in a flask or to collapse a metal can.



The cold sponge causes condensation of water vapor in the flask. Why does the water boil?

7. How is a salt made? Obtain a piece of copper about as large as a cent and about 10 milliliters of nitric acid. Pour a little acid over the copper in a glass dish. (*Caution*: Nitric acid burns skin, clothing, and wood. If it is spilled, rinse with water and immediately cover with baking soda. Do not breathe the brown fumes given off in this experiment. Have the room well ventilated so that the fumes quickly blow away.) Continue adding acid un-



Science Service

This rocket is launched from an airplane. In a rocket chemical energy is converted to mechanical energy.

til only a little copper remains. When all action has stopped, remove the copper and let the water evaporate. Observe what you find in the dish. It is a salt, copper nitrate.

8. May color changes indicate chemical changes? Obtain a cracker or a piece of raw potato, some tincture of iodine, and some photographer's hypo [sodium thiosulfate]. Make a solution of iodine by dropping about 15 drops of iodine into half a glass of water. Put a quarter of a teaspoonful of hypo into another glass half full of warm water. Dip the potato or cracker first into the iodine solution and then into the hypo. Dip it into the iodine again, and again into the hypo. Now pour the two solutions together. The hypo and iodine react to produce two new chemicals, both of which are colorless in water.

9. Is carbon dioxide heavier than air? Obtain a wide-mouthed jar or a baking pan. Make carbon dioxide either by use of soda and vinegar or from dry ice. Obtain some bubble-making material, either soap-and-water or prepared. Fill the pan or jar part full of carbon dioxide. Drop bubbles into it. Explain how this experiment shows that carbon dioxide is heavier than air. Fill some bubbles with carbon dioxide, and repeat.

10. Is there carbon in carbon dioxide? Fill a jar with carbon dioxide and cover it. Obtain some magnesium ribbon. Hold the ribbon with forceps and light it. Immediately remove the cover from the jar and thrust it into the carbon dioxide. Does it continue burning? Is carbon deposited on the jar? Where did the magnesium obtain the oxygen needed for burning?

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Paricutin volcano casts a fiery glow against the night sky as molten lava flows down its sides.

11. Does carbon dioxide form acid when dissolved in water? Obtain some blue litmus solution, or some blue litmus paper. Bubble carbon dioxide through the solution, or into a bottle holding the wet litmus paper. Explain your results.

12. Does the sun have sunspots? Obtain some heavily smoked glass or a heavily fogged photographic film. The dark, sky portion of an overexposed negative is about right, or two such films may be used together. You can safely look directly at the sun through these films. (Do not look at the sun through field glasses nor with your eyes uncovered.) If you can obtain a large round reading glass of good quality, you can cover it with dark film or smoked glass, and project an image of the sun on a piece of paper. When you hold the lens the right distance from the paper to get a clear, round image, you may be able to see images of the dark sunspots.

Some subjects for reports

1. The life and work of Joseph Priestly
2. The life and work of Lavoisier
3. The various kinds of clouds and weather they bring
4. Local geological formations of unusual interest
5. The local geological history—or how your locality was formed
6. Common chemical changes used in cooking
7. Solutions commonly used at home
8. Suspensions commonly used at home
9. How to make oil and water mix
10. The expanding universe hypothesis
11. Hypotheses regarding formation of the earth
12. The atomic-bomb project
13. Variable stars and new stars

1. What kind of material is air?

You know many things about air. You know that it can be used to blow up a balloon, and that you can measure the amount of air that the balloon will hold. This is good evidence that air is a real material. All material things are made of matter, and matter occupies space. You also know that air is elastic, because it can be compressed in the balloon. A thing is elastic when it will go back to its original shape after it has been forced in some way to change shape. Many elastic things have "bounce" or "snap."

You have probably done the experiment of weighing a football when it is quite full of air, and again when part of the air was permitted to escape. A football weighs less when it has less air in it, showing that air has weight. This is another kind of evidence that air is made up of matter, for matter has weight.

What is air? Air is not a single, simple material. Although all the parts of the air stay together quite well under ordinary conditions, sometimes one part of the air will do things that other parts will not do. You can

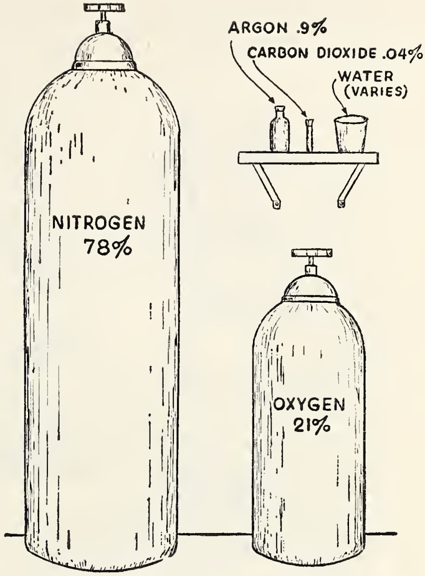
take the oxygen from the air and leave other things behind. If you float a candle on a piece of wood, light it, and turn a jar upside down over it, you can see the water rise slowly in the jar as the oxygen is used by the candle. The candle flame soon goes out. The gas formed by the burning candle is carbon dioxide, which slowly dissolves in the water and is removed from the jar.

Some things in the air vary in amount from time to time. Dust and smoke particles become mixed into the air and later settle from it. Water vapor may make up more of the air on a sticky, humid day than on a dry, cool day.

Scientists have studied the air near the surface of the earth many times. The following table shows the per cent of various gases which make up dry air. Of course air is never completely dry as it is found naturally.

GAS	PER CENT BY VOLUME
Nitrogen	78.3
Oxygen	20.99
Argon	.94
Carbon dioxide	.03
Hydrogen	.01
Neon	.0012
Helium	.0004

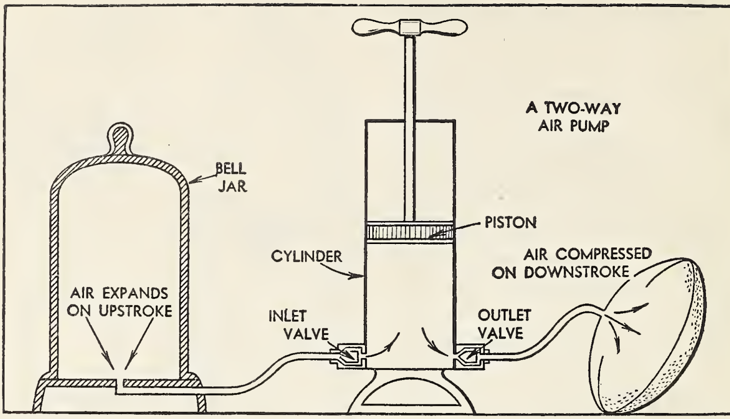
The gases of the air are not combined with each other, but are merely mixed together. You can remove one gas from the air without changing the other gases. There is more of the heavier carbon dioxide gas in the air near the earth's surface than at higher altitudes. Most of the very light hydrogen and helium found in the air are high above the earth.



Air is a mixture of gases and can be separated mechanically into its parts.

The various gases of the air are interesting to study. Carbon dioxide is so heavy that it may be poured from one open container to another. Have you ever made a jar of carbon dioxide and poured it over a burning candle in a small jar? The candle will go out, for carbon dioxide will not support burning.

Oxygen will support burning very well. It will also cause metals to rust. Enough oxygen dissolves in water to make it possible for fish and other water animals to breathe. Oxygen is the gas that we must have for breathing in order to live.



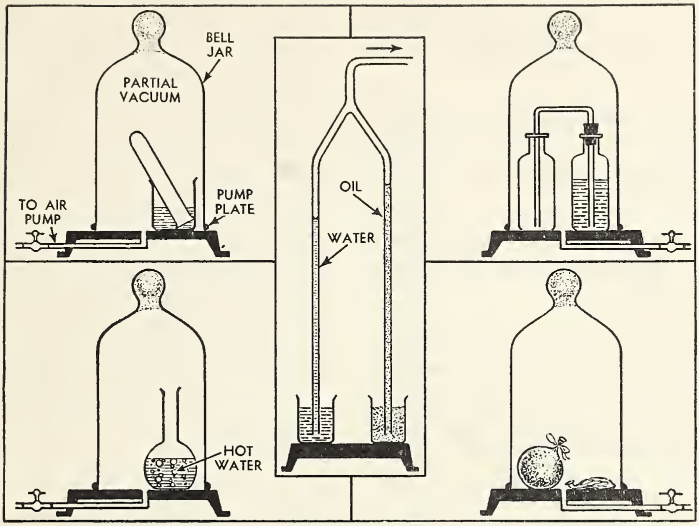
The direction of air movement in this type of pump is controlled by the construction of the valves and by the direction of movement of the piston.

Nitrogen is a gas which does not act readily with other things. If the air contained only nitrogen nothing would burn, and no animals could live in it. It thins the oxygen, which is a good thing. In an atmosphere of pure oxygen things burn readily. If you built a fire in a stove, in an atmosphere of pure oxygen, not only the fuel but the iron stove also would soon be burning vigorously. In pure oxygen animals become so active that they soon tire themselves out.

Why does air exert pressure? Air exerts pressure for two reasons. It exerts pressure upon surfaces because the gravity of the earth pulls it downward. If you place a book on your desk, the book exerts pressure on the desk because of its weight. Weight is the result of gravity pulling the book down against the desk.

Air also exerts pressure because it is a gas. The molecules of any gas move very rapidly in straight lines, until they strike against something. A molecule is the smallest particle of any kind of material. Because a great many molecules of air strike against most surfaces near the earth, they exert a constant pressure on the surface. If you pump up a football you increase the number of molecules which strike against the inside of the ball, making it firmer. What is the required pressure for a football?

Air does not exert pressure equally at all places. A cubic foot of air at sea level weighs about 1¼ ounces. At the top of a mountain three and a half miles high, a cubic foot of air weighs only half this much, or ⅝ of an ounce. The pressure of the air falls off rapidly as the elevation increases. At an elevation of about seven miles the air is so thin that its nature changes. This upper layer of air, which is called the strato-



These diagrams show how apparatus is arranged for experiments described in the text.

sphere, has no ordinary clouds nor storms. It is too thin to hold heat well. Most of the upper air is very cold, ranging far below zero, in temperature. There is a hot layer of air high above the earth, however, where the air first absorbs the sun's heat.

DEMONSTRATION: HOW IS AIR PRESSURE USED TO DO WORK?

What to use: Air pump, bell jar, plate, wax, flasks, bottles, stopper to fit one bottle, glass and rubber tubing, Y-tube, test tube, beaker, oil, water, balloons.

What to do: Each part of the diagram above shows the setup of an experiment depending upon air pressure. Perform as many as you can.

Put a test tube mouth down in a beaker containing enough water to cover it well. Pump air from the bell jar as long as bubbles continue to escape. When no more bubbles escape permit air to enter the jar. The air bubble remaining in the test tube shows how much the pump failed to remove.

In the second part set a flask of hot water under the bell jar and remove air as long as the water boils. If you put a thermometer in the flask you can discover that water does not always boil at 212 degrees.

In the third part connect the tubes as shown, and suck air from the open tube. Observe that the oil rises farther than the water. If you measure the height of the oil and water, and divide the height of the column of water by the height of the column of oil, you have the specific gravity of the oil.

Set up a siphon as shown. Test it in open air and under the bell jar when a partial vacuum is formed.

Put two balloons under the bell jar, one with its mouth open, the other containing a little air and with its mouth tied closed.

What was observed: State briefly what happened in each part of the demonstration.

What was learned: How does air pressure do work? How does reducing air pressure affect the boiling point? How does the weight of water compare with the weight of oil?

Exercise

Complete these sentences:

The air is about one-fifth —1— and about four-fifths —2—. Air, like all matter, occupies —3— and has —4— when acted upon by the force of gravity. The smallest particles of any material are called —5—. A material which has the ability to recover its original shape after being changed is —6—. Molecules of a —7— exert pressure by constantly striking against a surface. The gas which will support burning is —8—, and the gas formed by ordinary burning is —9—. The upper atmosphere is called the —10—.

2. What kind of material is water?

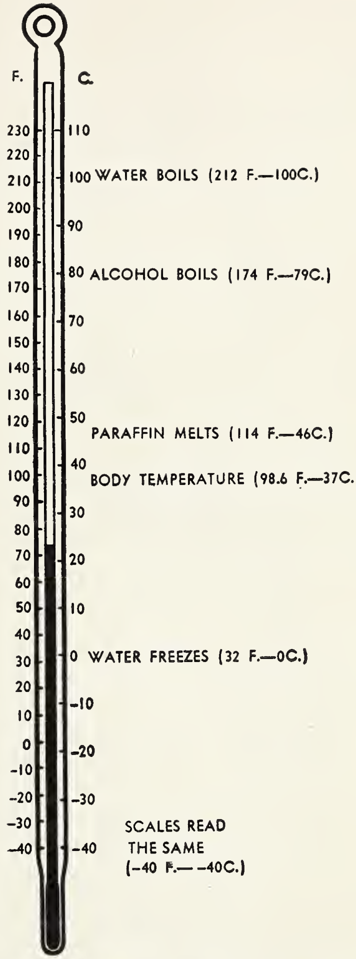
People can depend on certain things for their very lives, and still know very little about them. For several hundred years educated people believed that the earth was made of just four things, earth, air, fire, and water in various combinations. They actually thought that these four things were simple, pure substances. It was only after people began to experiment that they discovered what these four things really are.

What is water? Water is a chemical compound, composed of two parts hydrogen and one part oxygen by volume.

Water can be made from gases in the laboratory, but not by merely mixing them. Hydrogen can be prepared by pouring one of the common laboratory acids over a metal such as iron or zinc. A very lightweight gas is given off. This gas may be collected in a bottle. Fairly pure oxygen can be prepared in several ways. One way is to heat the red rust or oxide of mercury so that oxygen is given off as a gas and pure mercury metal remains behind.

If you should pour the oxygen and hydrogen together you would have a mixture. It would be made up of two gases, each keeping its own properties [essential individual characters].

As long as the oxygen and hydrogen remain cool, they are merely mixed together. But if a spark or flame should be brought into contact with the mixture, they would burn with a violent explosion. If there were too much of either gas to mix in the proportion of two parts hydrogen to one part oxygen, it would be left unchanged by the explosion. But the parts which would com-

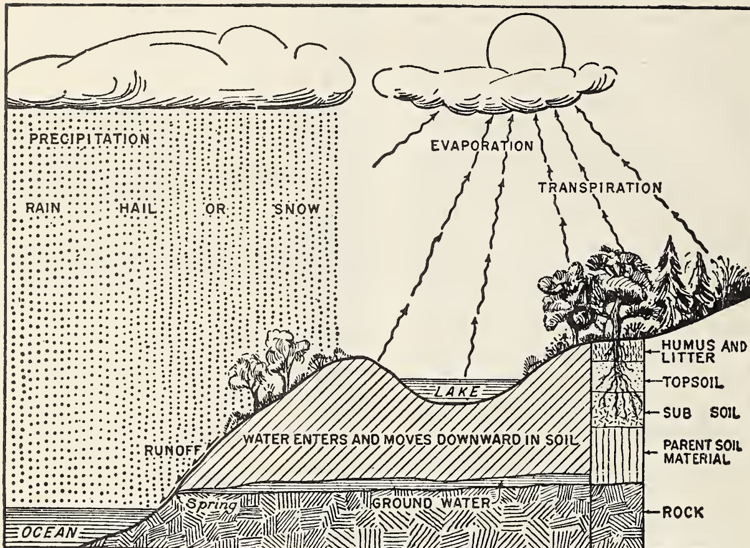


Compare the temperatures on the two thermometer scales at which the scales read the same. What is room temperature on each scale? Which thermometer scale has longer degrees?

bine would no longer be hydrogen and oxygen. They would be chemically combined in the form of water. Each chemical compound is made up of definite proportions of the simpler materials of which it is composed. And when things change chemically heat is either taken in or given off. The amount of heat given off by an explosive mixture of hydrogen and oxygen is very great.

What is unusual about water? Water is an unusual chemical in several ways. It is the only common chemical that exists in all three states at temperatures common in our climate. It will dissolve more things than will any other common chemical. And it will hold more heat than will any other common material.

We are so familiar with the three states of water that we need only be reminded that they are the liquid water, the solid ice, and the gaseous water vapor. Water is exactly the same chemically in its three forms, that is, it is always two parts hydrogen and one part oxygen as expressed in the formula H_2O. But physically it is different. In ice, the molecules form patterns which make up crystals. The molecules in ice may vibrate, but they do not move much from place to place. In liquid water, the molecules are constantly moving around because they have so much energy. They cannot move beyond a certain limit because of the pull of other water molecules. Some molecules, however, may gain extra speed and escape from the surface in the process of evaporation. In the gas form, water vapor, the molecules are like those of other gases. They move at high speeds in straight lines



U. S. Forest Service

The water cycle is not only a source of water needed by living things, but it is also a source of useful energy.

until they bump into something which will cause a change of direction.

Water holds heat in two ways. One way depends upon the temperature of the water. The other way depends upon its state. If we heat one gram of water one degree centigrade, one calorie of heat is required. The calorie is the unit of measuring heat. If we start with a gram of ice at a temperature of 0 degrees centigrade (which is the same as 32 degrees Fahrenheit), it requires about 80 calories of heat to change it to water. This change does not warm the water at all, for its temperature will still be zero. Then if we want to heat this water to the boiling point, another 100 calories will be needed, one for each degree of increase in temperature. Water boils at 100 degrees centigrade. But it will not start boiling until more heat is added. Not until 540 more calories have been added will all the gram of water become water vapor.

Even when water dries from wet clothes on a line, heat is added to the water. The heat is taken from the clothing and from the surrounding air. You can test this idea by wetting your finger and blowing on it. As your finger dries, it loses heat.

Of course when water vapor changes back to water, and water to ice, all the heat originally taken in is given off. When we condense steam in our radiators, we expect the heat to come from

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This glacier is a slow-moving river of ice made from the snows of thousands of winters.

the water vapor and warm the room. A hot water radiator also gives off heat lost by the cooling water. You can even warm a very cold room by putting a tub of water in it and letting it freeze. The heat given off by the freezing water warms the room.

The amount of heat that would warm a gram of water one degree centigrade would warm two grams of alcohol, six grams of glass, nine grams of iron, or 30 grams of lead about the same amount.

What things will water dissolve? When we cook vegetables we expect the salt we throw into the water to disappear. This does not mean that the salt no longer exists, but that it has been broken into particles too small for us to see. When the water wets the salt, its particles loosen some of the molecules of the salt crystal. These freed salt molecules begin to move out among the molecules of the water. After a while all the salt molecules are free and are scattered quite evenly through the water. Molecules are much too small to see. Of course we can put so much salt into water that only part of it will dissolve. There is not an unlimited amount of space for other molecules among the water molecules. Any material in which another material dissolves is called a solvent.

Water will dissolve, in a similar way, a great many things. Sugar, limestone rock, soda, alcohol, and washing powders are common things which will dissolve fairly readily. Other things, such as fats, wood, and brick dissolve very slowly, if at all.

If we want to dissolve crystals of iodine in water, we can use other materials to help. If we put alcohol on the crystals, they will dissolve rapidly, and we can then dissolve the alcohol solution of iodine in water. We can add a chemical, potassium iodide, to water to increase its ability to dissolve iodine.

Water will not dissolve things it will not wet. We can increase the ability of water to wet things in several ways. If you have a powder which will not dissolve, it may first be wet with alcohol and then dissolved in water. Or you may add a little of one of the common soapless detergents used for dishwashing to the water. You may have noticed that the grease on the dishes dissolves readily in hot water to which one of these detergents has been added.

We may say that a solution is formed when the molecules of a material are distributed uniformly among the molecules of another material.

DEMONSTRATION: OF WHAT IS WATER MADE?

What to use: Bottle with two-hole stopper to fit, thistle funnel tube, glass and rubber delivery tubes, test tube, burner, zinc or iron filings, hydrochloric acid.

What to do: Set up a standard gas generator bottle. Put about half an inch of water in the bottom, being sure that the end of the thistle tube dips

into the water. Put a heaped tablespoonful of zinc or iron filings into the bottle. Have the delivery tube ready with the end drawn to a jet. Pour about 20 milliliters of hydrochloric acid into the thistle tube.

Collect the gas given off by holding a cool test tube upside down over the end of the delivery tube. Carry the test tube mouth down to the lighted burner, and ignite the gas. It should burn with a loud pop. Continue testing the gas until it burns quietly with no noticeable explosion. (Caution: Do not let the gas escaping from the tube become ignited.)

Observe the inside of the test tube carefully in order to note the formation of a mist of water on the inside of the glass.

What was observed: How does the acid react with the metal? Could you see a flame as the hydrogen exploded? Was a cloud of water drops visible at any time?

What was learned: How is gas lighter than air collected? Where did the oxygen needed for burning come from? What is formed when hydrogen burns in air?

Exercise

Complete these sentences:

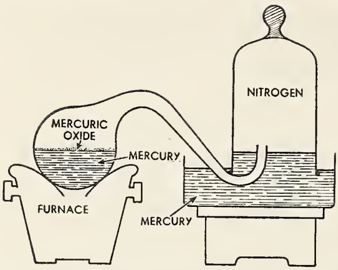
Water is a chemical compound composed of two parts —1— and one part —2— by volume. Every chemical —3— is made up of definite proportions of the simple substances of which it is composed. The amount of heat required to raise the temperature of one gram of water one degree centigrade is one —4—. The gaseous state of water is —5—. A total of —6— calories is required to change one gram of ice to water vapor. Molecules of —7— remained fixed in position among other molecules. Molecules of —8— move about, but are held in the material by the attraction of other molecules. Molecules of —9— move freely in straight lines. In a —10— the molecules of the dissolved material are scattered evenly among the molecules of the liquid.

3. What is matter?

A green leaf fluttering in the wind is so common a sight that we do not spend time marveling at it. Yet it is really marvelous. A few months before the leaf was not there. The materials of which it is made were in the soil, in the air, and perhaps stored in the tree itself. The energy of the wind came from the sun. Under ordinary conditions we can tell the difference between matter and energy. But the scientist sometimes reaches a point where he cannot say that there is any difference.

What are ordinary materials? The common materials around us are either elements or chemical compounds. An element is one of the 96 simple materials of which other materials are made. Compounds are made up of two or more elements. Of course many materials, such as rocks, are made up of several compounds mixed together.

We do not see many of the ele-



This apparatus was used by the French scientist, Lavoisier, to show that oxygen from the air can combine with a metal.

ments in their pure state. Oxygen, nitrogen, iron, carbon, mercury, and copper are some of the more familiar elements. Most of the elements are usually encountered in compounds. Some elements are so rare that they have been found only after patient research. Four elements now known do not exist on the earth naturally but have been manufactured from other elements in the atomic laboratories.

The elements can be grouped roughly into classes. Many of them are metals. Others are called acid formers, for they combine with hydrogen and other materials to form a class of chemicals called acids. Acids are sour substances which turn litmus paper red and which react with some metals. There are several elements which are not metals and which will not form acids. Some of these will not react with anything else to form compounds. The elements have two kinds of labels. One is the name, the other a letter or a group of letters called a symbol. The table below lists some of the better-known elements.

A chemical compound may be represented by a group of letters which show the elements of which it is composed and in what proportions. Thus when carbon burns in oxygen, carbon dioxide is formed. We can summarize this reaction with this equation: $C + O_2 \rightarrow CO_2$. This equation indicates that for burning each atom of carbon two atoms of oxygen are required.

There are hundreds of thousands of chemical compounds. Each of them is identified by a chemical formula, made up of letters and numbers indicating the proportions of elements of which they are composed. Names of compounds, such as that of DDT, are sometimes quite long if they describe the compound exactly. DDT is not a formula.

The smallest part of a compound is called a molecule. The smallest part of an element is called an atom. Molecules are made up of atoms.

METALS	*SYMBOL*	*ACID FORMERS*	*SYMBOL*	*NEUTRAL*	*SYMBOL*
Iron	**Fe**	**Sulfur**	**S**	**Hydrogen**	**H**
Aluminum	**Al**	**Carbon**	**C**	**Oxygen**	**O**
Calcium	**Ca**	**Nitrogen**	**N**	**Neon**	**Ne**
Sodium	**Na**	**Phosphorus**	**P**	**Helium**	**He**
Potassium	**K**	**Iodine**	**I**	**Argon**	**A**
Copper	**Cu**	**Chlorine**	**Cl**		
Mercury	**Hg**	**Fluorine**	**F**		

Of what are atoms made? All atoms are made up of the same kinds of energy particles. They differ in that there are different numbers of particles in the different kinds of atoms. Three kinds of energy particles are protons, neutrons, and electrons. Protons and electrons have electrical charges and attract each other, somewhat as north and south poles of magnets attract. Neutrons do not have any electrical charge.

Protons and neutrons seem to be about the same in mass or weight. The electron is much lighter than either. A proton weighs 1847 times as much as an electron.

The simplest atom is that of hydrogen. It contains only one proton and one electron. The electron travels around the proton, somewhat as the earth goes around the sun.

The next simplest element is helium, for its atom contains only two electrons, two protons, and two neutrons. It thus weighs about four times as much as the hydrogen atom. The two protons and two neutrons are bunched together in the center of the atom and form a nucleus, while the two protons revolve around the outside.

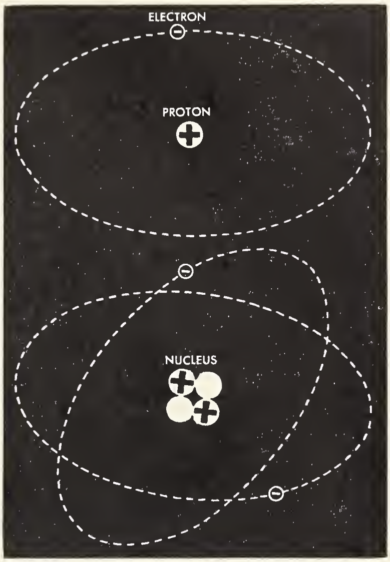
The next element in order of weight is lithium, a very light metal. Lithium atoms contain three electrons, and three protons and four neutrons.

You can form the following conclusions about atoms:

1. The weight of the atom is chiefly determined by the sum of the protons and neutrons.

2. An atom has the same number of electrons and protons.

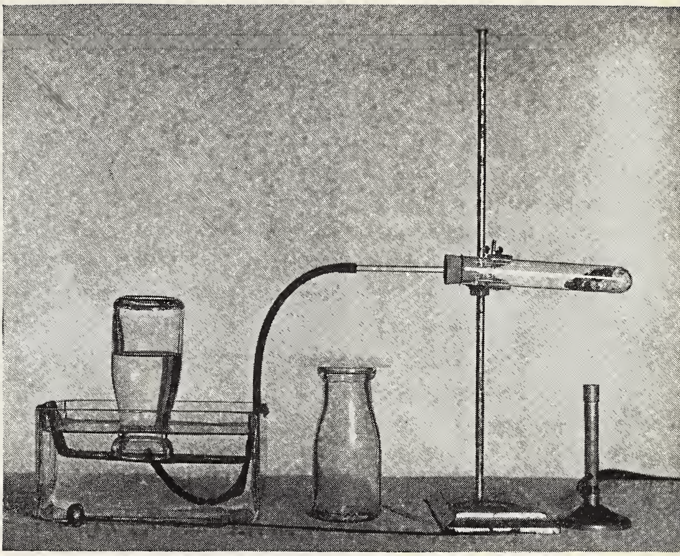
3. The number of an element (starting with hydrogen as 1) is the same as the number of electrons which revolve around the nucleus.



The hydrogen atom consists of one proton and one electron. The helium atom consists of two protons, two electrons, and two neutrons.

Thus the atomic number of carbon is 6 and its atomic weight is 12. The carbon atom has six electrons revolving around the nucleus, and a nucleus of six protons and six neutrons (total—12).

What are the properties of matter? We say that matter has two kinds of properties, physical properties and chemical properties. Chemical properties describe the way a material acts



You should arrange the apparatus in this way to prepare oxygen. Note that one bottle is covered with a piece of glass.

when it combines or reacts with other chemicals. Physical properties describe the way the material acts when energy is applied to it.

Inertia is one physical property of all matter. That is, all matter resists being moved, and resists being stopped if it is once in motion. Ability of a material to dissolve, to hold heat, to bounce, and to withstand breaking and its size are physical properties. The state of matter, whether solid, liquid, or gas, is a physical property.

Another physical property of matter is its mass. Mass is the amount of matter in an object. Mass is not the same as weight, for an object has weight only when the gravitation of the earth acts on it. Matter has mass regardless of where it is. Finding the amount of inertia an object has is the best way to measure its mass.

Chemical properties relate to the way a material reacts with other materials. A material which will not react is said to be chemically inert. A material, such as oxygen, which reacts with many things, is said to be chemically active. Saying that a thing is acid describes some of its chemical properties.

DEMONSTRATION: HOW DOES OXYGEN TAKE PART IN CHEMICAL CHANGE?

What to use: Test tube, rubber stopper, delivery tube, ring stand, clamp, manganese dioxide, potassium chlorate, burner, gas collecting bottles, glass plates, trough, steel wool,

magnesium ribbon, sulfur, deflagrating spoon, splint, litmus paper, forceps.

What to do: Set up the apparatus as shown in the illustration on page 38. Mix a teaspoonful each of potassium chlorate and manganese dioxide in the tube, and heat it. When bubbles are given off freely, collect four bottles of the gas.

Test the first bottle of gas with a glowing splint.

For a control (comparison) burn a small piece of magnesium ribbon in air. Hold the metal with forceps. Burn a second strip in oxygen.

Burn sulfur in the deflagrating spoon in the third bottle. Put a piece of wet litmus paper in the mouth of the bottle.

Wrap steel wool loosely around the handle of the spoon, heat it in the flame, and thrust it into the fourth bottle of oxygen. If there is water in the bottom of the bottle, danger of breakage is lessened.

What was observed: Make notes on what was observed.

What was learned: Does a chemical change produce a new substance? Give at least six examples from this demonstration to illustrate your answer.

Exercise

Complete these sentences:

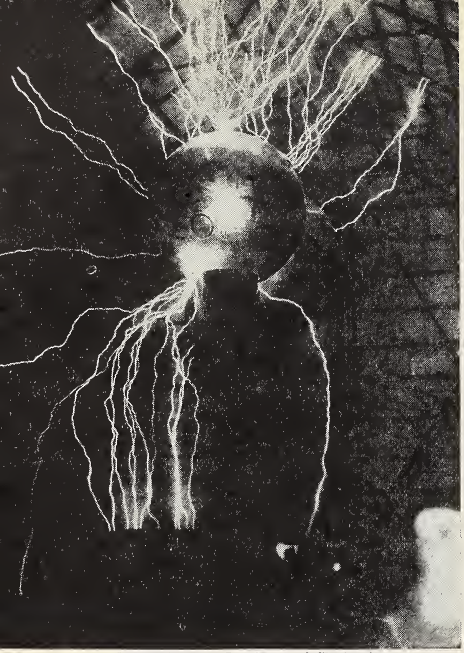
The smallest particle of an element is the —1—. The smallest particle of a compound is the —2—. When atoms combine they form —3—. The center or nucleus of the atom always includes —4— and all but hydrogen atoms contain —5—. The energy particles which revolve around the outside of the atom are the —6—. Table salt, which is NaCl, contains in each molecule one atom of —7— and one atom of —8—. When elements combine they form —9—.

4. Can we obtain energy from matter?

There is plenty of energy in the universe, but we cannot easily use most of it. The pull of the sun and moon on the oceans makes a tide which contains large amounts of energy. A great deal of energy is absorbed by our western desert lands on a sunny day. We have found no way of collecting the energy of the tides or of the sunshine that is cheap enough that we can afford it. We must get energy from some source that is convenient and reasonably cheap.

There are four different kinds of energy available to us. We can use the energy of the sun in limited ways, as when we obtain salt left from sea water evaporated by the heat of the sun. We can use the energy stored in moving things, as we do when we use a windmill to pump water. We can release energy stored in some chemicals. That is what we do when we build a fire. And we can obtain the energy stored in atoms.

What is solar energy? The energy of the sun is called solar energy. The sun is actually the source of almost all other kinds of energy available to us. Its rays provide energy used by plants which we use for food, clothing, fuel, and many other needs. Sunshine provides the energy which



Massachusetts Institute of Technology

This illustration shows the discharge of electrical energy from an atom smasher. This energy, when properly directed, is sufficient to change the nature of matter. With atom smashers one kind of matter may be changed to another.

makes winds blow and water evaporate.

The energy of the sun contains many kinds of radiant energy. Radiant energy travels through space in straight lines at the speed of 186,000 miles per second. Common forms of radiant energy we receive from the sun are light, infrared or radiant heat rays, and ultraviolet energy. The sun also gives off energy in the form of charged particles, similar to the particles which make up atoms.

What is mechanical energy? The energy held by an object in motion is mechanical energy. We obtain mechanical energy chiefly from wind and running water. Both are useful sources of energy. Wind is not very dependable, and windmills are fairly expensive. But for many uses the wind can provide energy. Running water is not available everywhere, but where it is it is perhaps the cheapest source of energy.

The energy of wind and running water comes from two natural forces. The sun provides the energy which enables the molecules of air or water to gain speed. As they increase in speed, they rise into the air. As they cool gravity pulls them back down to the earth. Thus these materials are lifted by solar energy and caused to fall by gravity.

Can we use chemical energy? Many activities depend directly upon chemical energy. Most industries and railroads operate on energy obtained from burning coal, either for producing steam or for generating electricity. More houses are heated by coal than by any other single fuel. We burn gasoline and fuel oil in many kinds of engines. We burn wood in stoves for heat. We use chemical energy in dry cells to obtain electricity.

The most common way of releasing chemical energy is by burning. Burning changes fuel and oxygen into carbon dioxide and water. Coke and hard coal are mostly carbon. Most fuels are compounds of carbon and hydro-

This man is pouring melted glass. Glass is usually melted by use of a very hot gas flame.

Brookhaven National Laboratory

A Geiger-Muller counter is used to trace the movement of a laboratory-produced radioactive chemical from the soil into various parts of the plant. This experiment gives information about how plants use minerals.

gen. As you know, both of these elements will burn in oxygen. The energy stored in fuels came originally from the sun, for all of our common fuels originated from plants. Coal and oil have held the stored energy from the sun for millions of years.

Burning releases energy in two forms, as radiant heat and light. If fuel is burned in a furnace these two forms of radiant energy are absorbed by the walls of the furnace and become heat. Heat is the energy which makes molecules vibrate or move. Molecules of solids vibrate more rapidly as they become warmer. Molecules of liquids move more rapidly, and some of them gain enough energy to escape from the attractive force of other molecules in the liquid, as the liquid is heated. Molecules of gases gain speed as they become hotter.

Can atomic energy be released? There is energy in all parts of the atom. Certainly the electrons must have energy to revolve endlessly around the nucleus. But the greatest store of energy seems to be in the nucleus itself. There is some kind of force which holds the protons and neutrons together. When these protons and neutrons in the nucleus are broken apart, the energy is given off.

Most elements do not give off atomic energy naturally. Only a few of the heaviest do so. The first of these to be discovered was radium. The element which is now used to give off atomic energy is uranium. Uranium 238 has 92 protons and 146 neutrons in its neucleus. Another similar element, uranium 235, also yields atomic energy. In order to obtain energy from the nucleus of an atom, it must be broken apart in some way.

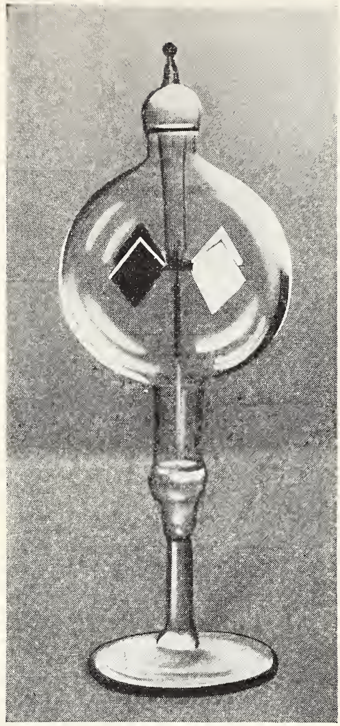
There are several kinds of atom smashers with such strange names as cyclotrons, betatrons, and atomic piles. Each of these performs a somewhat similar function. It starts some particle of matter in such violent motion that, when it strikes an atom, it causes the nucleus of the atom to break apart. The most effective of the atomic bullets is the neutron.

When enough uranium is pres-

ent in one place, and a bombardment of neutrons strikes the nuclei of the uranium atoms, they break up. The products formed are two lighter elements, barium and krypton, and free neutrons. These neutrons in turn strike other atoms, causing them to give off more neutrons. Such a series of reactions is called a chain reaction. The energy of the nucleus is given off in two forms. One form is radiant energy, and includes heat, light, and other rays. The shortest rays, called gamma rays, can pass through most ordinary substances. The other form of energy consists of particles. The particles, which include neutrons and charged particles, move with terrific speed. When these particles bump into other kinds of matter, they produce a great quantity of heat.

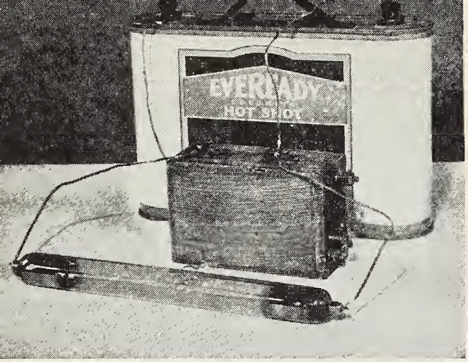
The practical use of atomic energy depends upon using the heat released to operate engines and to produce electricity. In order to do this, the energy-producing material is mixed with some less active material, such as carbon, and the heat generated is used to heat water or some other material.

For safety the radiations and moving particles, which cause fatal internal burns, must be absorbed in some heavy container. Several feet of concrete and lead are required to protect a person from danger from these rays. Thus all power plants using atomic energy must at present be quite large in order to be safe. There is perhaps enough uranium in the world to release radiations which might destroy all living things on earth if all its energy were released at one time.



A radiometer consists of vanes mounted on a needle point within a partial vacuum. The vanes turn when radiant energy strikes upon them.

The presence of materials giving off gamma rays can be detected by a device called a Geiger counter. Rays cause the device to give off clicks or a buzzing noise when gamma rays are present. It is particularly important to know when radioactive materials are present in order to protect people from their effects.



This apparatus shows an old automobile induction coil attached to a neon tube. The induction coil sends an electrical discharge through the neon gas, causing it to glow.

DEMONSTRATION: MAY ONE KIND OF ENERGY PRODUCE ANOTHER?

What to use: Dry cells or hot spark battery, induction or automobile spark coil, aurora tube (neon), radiometer, metal disk, burner, forceps.

What to do: Set up the apparatus as shown in the photograph. Observe the glowing light. Feel the tube to learn if it becomes hot. Electrons from the coil cause the gas in the tube to glow. Set the radiometer in dim light. Heat the metal disk in the flame and then hold it near the radiometer.

What was observed: Was there any difference in brightness of various parts of the tube? Does the coil change the current in any way?

What was learned: How does the neon sign operate? Can one kind of energy be transformed to another? What kind of energy comes from the tube? What kind of energy does a hot object give off?

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: SOLAR ENERGY, MECHANICAL ENERGY, CHEMICAL ENERGY, ATOMIC ENERGY. In the correct column write the following words: uranium, the sun, running water, fire, dry cells, cause of winds, energy of winds, gamma rays, heat, light, falling water, charged particles, oxidation, moving objects.

5. Where can we obtain needed materials?

Every material which we use must come from the earth, the air, the ocean, or the sun. We are quite limited in our ability to obtain these materials, for we cannot dig miles into the earth, nor extract from the ocean materials that exist in very small amounts. We must hunt till we find needed materials in a form that we can obtain and use.

We may use natural materials either as sources of chemicals or in their natural state. We are so accustomed to seeing sand, water, and rock used that we hardly think of them as being important materials. Yet these common minerals are of great importance to us.

What materials are used in their natural state? Several materials are used either as they come from the earth, or without much change. Clay is one of the minerals which is useful in its natural state. Clay is used for making brick and pottery, for purifying oils, and for a dry-cleaning fluid.

Sand is used for making cement, for filtering water, for making molds in which metal is poured, for grinding and polish-

ing, and similar common uses. Gravel is used in making concrete, for filtering water, and for surfacing roads.

Rock is used for paving, for buildings, for fences, and for dams. Limestone rock is used in purifying iron. While we do not ordinarily think of soil as a source of minerals, we use it constantly as a source of food for ourselves and all other animals.

What materials do rocks provide? Many common rocks are useful sources of chemicals. Limestone, chemically, is impure calcium carbonate ($CaCO_3$). In order to make lime from limestone, it is heated until carbon dioxide is driven off and calcium oxide remains. The equation is $CaCO_3 \rightarrow CaO + CO_2$. Lime, which is calcium oxide, is useful for a great number of purposes. It is one of the materials used, along with clay, in making cements. It is used with sand to make glass. Plaster and the glaze of pottery both require lime. Leather is tanned by using lime to remove the hair from the hide. In fact, lime is one of the most important chemicals used in industry. It is also used as a fertilizer to "sweeten" sour or acid land and to provide plant food.

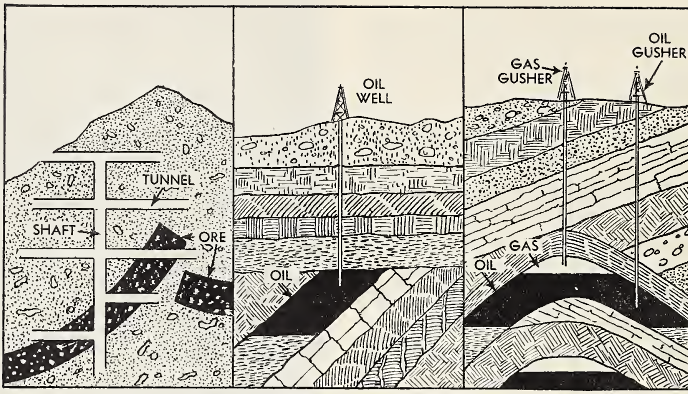
Chemically when lime reacts with water, it forms a base. A base will react with acids and produces a class of chemicals called salts. Bases turn litmus paper blue and taste bitter.

Common table salt is another source of chemicals. Some salt is mined as rock salt, while some is produced from ocean water. Lye, soda, and chlorine are materials made from salt. Lye is used in making soap. Soda is used in making many products, including glass. Chlorine is used for purifying drinking water. Table salt will also react with sulfuric acid and make hydrochloric acid. Lye is a base—in fact, one of the strongest bases. It is so strong that it will seriously burn the skin if it comes into contact with it.

Eimco Corporation

Much automatic machinery is used underground in collecting ores. This machine scoops up the ore after it has been blasted from the mineral vein.

Where are coal and oil found? Coal and oil are quite scarce materials as compared with clay, limestone, and salt. Layers of coal may exist in the earth's crust at



The usual mine is dug into the earth. Oil may flow from wells where gas exists underground, but often it must be pumped from the ground. Oil is commonly held in porous rocks between layers of more solid rock.

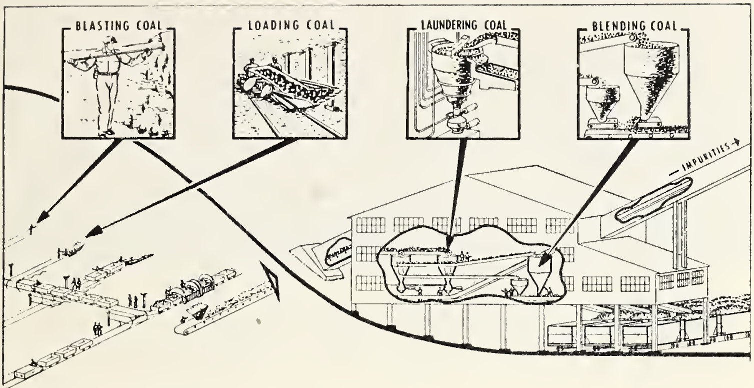
various depths. In some places coal is so close to the surface that it can be dug with power shovels. In other places it is found thousands of feet underground.

Oil is found underground only when it is trapped between rocks which prevent its escaping. Even where oil was once present, much of it has escaped because these rock-layer traps did not develop as the earth' crust changed and shifted. Oil is ordinarily held in the spaces of porous sand or shale (a claylike rock), with some nonporous rock layer above the porous layer. Natural gas was formed under the same conditions that produced oil, and now exists only where it is trapped underground. Most gas and oil exist at considerable depths underground.

What are ores? An ore is any mineral from which a metal is extracted. Sometimes the name ore is applied to other minerals from which nonmetals, such as sulfur, are obtained. Most common ores are chemical compounds of one or more metals with one or more of the acid formers—sulfur, chlorine, phosphorus, or oxygen. Some of the rarer elements form highly valuable ores.

Iron is found combined with oxygen to form different types of ores. Two common iron ores are called hematite and magnetite. Iron ores are brown or brownish-black in color, sometimes heavy and sometimes light and porous. In addition to the high-grade ores, from which a large amount of iron may be removed, there are millions of tons of low-grade ores, from which enough iron cannot be obtained to pay for the cost of purifying the ore.

The chief ore from which aluminum is obtained is called bauxite [bôks′īt] and is a combination of aluminum, hydrogen, and oxy-



Bituminous Coal Institute

This diagram shows the essential steps of mining coal and of preparing it for market.

gen. Most bauxite in this country is produced in Arkansas. Ordinary clay is not a practical ore, for the cost of obtaining the aluminum from it is high.

Another of the important metals is zinc. It is obtained from the ore zinc blende, which is a chemical compound containing zinc and sulfur. Other zinc compounds are zinc carbonate and a compound containing zinc, silicon, and oxygen. The chief ore of mercury is also a compound of sulfur.

One of the most important of all metals is copper. Sometimes copper is found in its pure state, but usually it is obtained from ores which contain sulfur or carbon and oxygen in addition to the metal. Because of the brilliance of the blues and greens of some copper compounds, copper ores are the most beautiful found in the United States. Some copper ores are polished and used in making ornaments.

Gold and silver are not important metals, compared with zinc, copper, and iron. Of the two, silver is much more useful because of the amount needed in making photographic films and paper. Both gold and silver are found in an uncombined state, either as nuggets or as lumps in rocks. Silver is often found combined with other elements, gold rarely so.

DEMONSTRATION: WHAT MATERIALS DOES LIMESTONE CONTAIN?

What to use: Burner, iron wire, ring stand, evaporating dish, litmus paper, limestone, limewater, hydrochloric acid, gas generator bottle.

What to do: Put a piece of limestone about the size of a bean into a dish with enough water to cover it. Test the water with red litmus paper.

Wrap a piece of wire around a piece of limestone, so that you can lay the wire across the stand. Heat the limestone with a blue flame until it begins to crumble. Drop the heated

limestone into the dish of water. Test it again with red litmus.

Put some limestone into a generator bottle and pour acid over it. Bubble some of the gas given off through limewater. If the limewater turns white, the gas is carbon dioxide. Test the gas with a burning stick or candle to see if it will support burning.

What was observed: Does limestone change in appearance when it is heated? Does the red litmus turn blue, indicating the presence of a base before heating? After? What gas is given off by limestone when it is decomposed chemically?

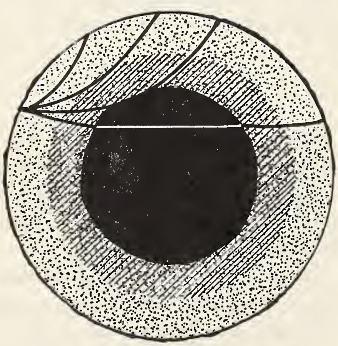
What was learned: State three things you have learned about limestone.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: clay, limestone, chemically changed, base, lime, lye, coal, oil, trapped, ore, iron, copper, litmus.

6. What materials does the earth contain?

When you go for a walk in the country, you do not see much gold ore, coal, or even pure clay around you. Instead you see mostly useless looking rocks, gravel, and soil. In a way these rocks are useless, for we cannot use them directly to make valuable products. But they are the stuff of which the earth is made.



If the earth were equally dense throughout, earthquake waves would travel in straight lines. Instead, they travel in curves, which indicates that the rock becomes denser with depth. Can you find the four zones of rock?

The apparently useless rocks provide the ground we live on. They may eventually become soil. The soil is perhaps our most important single source of wealth. It is from the soil that we get our food.

What is the interior of the earth like? Although we cannot use materials from the interior of the earth, nor explore it directly, it is interesting to know of what it is probably made, and how we gain information about it. Scientists think that the earth was first formed from materials which were completely melted and that the present earth was formed by these materials as they cooled.

Since it is about 4000 miles to the center of the earth, it is difficult to know what the inside of the earth is like. Yet careful observations make it possible to make quite accurate estimates regarding the earth's interior.

One source of information is measurement of earthquake waves. These waves move

U. S. Geological Survey

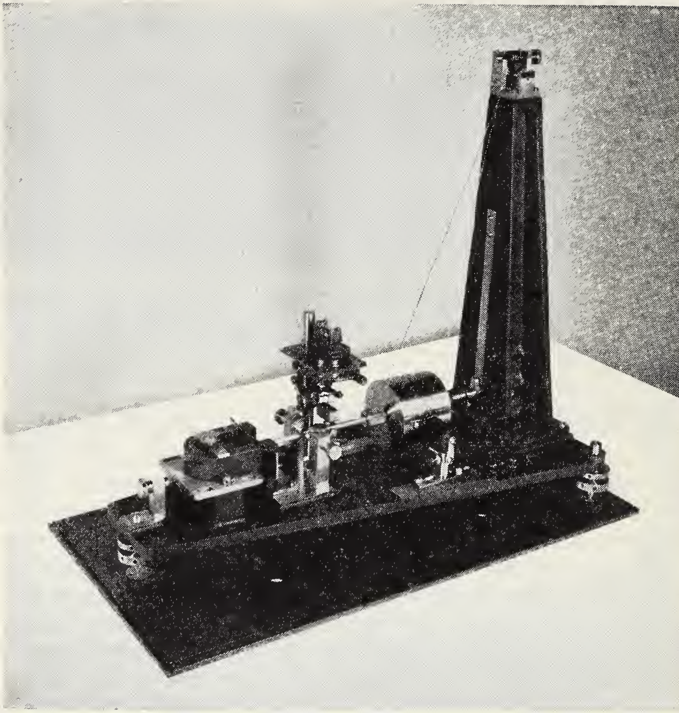
When the earth was younger, lava flowed on its surface much of the time. Flows such as this one which occurred in Hawaii are rare today because the earth is comparatively cool.

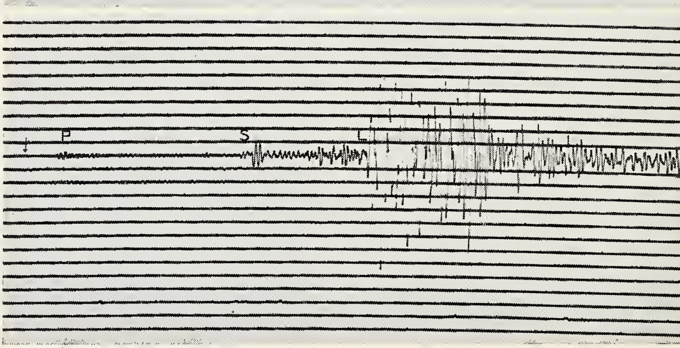
through different types of material at different speeds. This speed is about 3.3 miles per second in surface rocks and 4.8 miles per second in the next lower layer. As the wave spreads over the earth, accurate measurements of both the intensity of the wave and the time of its occurrence are made. The device used to measure earthquakes is called the seismograph. Measurements from various areas are compared, and the path of the wave is calculated.

Then too, the gravitational pull of the earth on the moon and on other planets is an indication of its mass, for gravitation is in proportion to mass. The force with which the earth spins is another indication of the condition of its interior.

From all these considerations it is believed that no large part of the earth is now melted. Instead, it is likely that the outer layer or the "crust" of the earth is made up of ordinary rock and is from 30 to 50 miles thick. Next is a mixture of silicates of iron and magnesium about 1000 miles in thickness. These rocks are similar to the black volcanic rock, basalt. For another 800 miles this layer gradually changes from silicate rocks to a central core of nickel and iron. This central core is probably a tremendously compressed, stiff fluid. The density of the earth is about 5½ times that of water. The density of surface rocks is only 2.8 times as great as that of water, which indicates that the interior is of heavier materials than the surface.

What are the common types of rocks? Rocks may be grouped either according to the way in which they were formed, or according to their composition. There are three general ways in which rocks were formed. Those which cooled from the melted state are called igneous rocks. Those which were formed from materials deposited by wind or water are called sedimentary rocks. Rocks which have been changed by heat, pressure, and





U. S. Coast and Geodetic Survey

A seismograph (*top*) is a device for recording movement of the earth's crust. It consists essentially of a heavy weight and of devices for recording earth movement. Such a record, called a seismogram, is shown by a wavy line (*bottom*).

chemical action are called metamorphic rocks.

There are two large groups of igneous rocks. One group is represented by the granites which contain quartz, feldspar (a clay-

like rock), and mica. The chemicals in these rocks are largely compounds of silicon, aluminum, and sometimes sodium or potassium, although several other elements are found in some rocks. The other kind of igneous rocks are represented by basalt. Basalt is a fine-grained black or brown rock and contains considerable iron and magnesium.

Sedimentary rocks are formed in many ways. When clay, sand, and gravel settle from water they are usually sorted and deposited in layers. As these materials settle they may form rocks. Clay forms shale, sand forms sandstone, and gravel forms conglomerate. Materials which dissolve from rocks and are deposited make another type of sedimentary rock. Mineral veins and deposits in caves are of this type. Still another type of sedimentary rock, limestone, is deposited as the shells, and skeletons of water animals fall to the bottom of the ocean or lake.

Any kind of rock may be changed in form as the earth changes. When lava from a volcano flows either underground or on the surface it may melt, bake, or otherwise change rocks. Water heated to extreme temperatures changes rocks. Pressure makes rocks more solid. These changes usually cause the rock to change in appearance. The crystals of metamorphic rocks are generally rather fine.

What are the common rocks? In your rock collections you probably have many common rocks, and you probably are able to recognize them well enough to name many of them at sight. Yet the chemical composition of these rocks is not indicated by their names.

There are a few common minerals which occur in most rocks. The quartz rocks contain the element silicon. The feldspars contain aluminum. The basalt rocks contain iron. The limestones contain calcium. The proportions of the common elements in the earth's crust are shown in the following table:

ELEMENT	PART OF THE EARTH'S CRUST BY WEIGHT
Oxygen	One-half
Silicon	One-fourth
Aluminum	One-twelfth
Iron	One-twentieth
Calcium	One-thirtieth
Potassium	One-thirty-fifth
Sodium	One-fortieth

Since these elements, in com-

CHEMICAL	IGNEOUS FORMS	SEDIMENT	SEDIMENTARY ROCK	METAMORPHIC ROCK
Silicon dioxide	Quartz	Sand	Sandstone	Quartzite
Calcium carbonate	Tuff	Lime, shells	Limestone	Marble
Aluminum silicates	Feldspar	Clay	Shale	Slate
Carbon	Carbon dioxide, diamond	Peat	Soft coal	Hard coal
Mixtures	Granite	....	....	Gneiss
Mixtures	Basalt	....	....	Schists

bination with each other, form about 95 per cent of the earth's crust, you can know the nature of most rocks if you know the forms in which these elements most commonly occur. The table summarizes information about rocks and organizes it in such a way that you can see the relation between different types of rocks.

To read this table, you may proceed as follows: When silicon dioxide is in igneous form it is quartz. Quartz breaks up to form sand when eroded and deposited by water. Sand is made compact to form sandstone. Sandstone under proper conditions may form quartzite.

The table makes things appear somewhat simpler than they really are. Since granite contains both feldspar and quartz, these minerals may be separated when granite is broken up, and each may form its own type of rock material thereafter. That is, both sand and shale may be products of erosion of granite. The metamorphic rocks may be broken up to form sediments, as is the case when slate weathers to form clay.

Some igneous rocks may form metamorphic rocks directly without going through intermediate stages. Careful study of this table is well worth your time, particularly if you have a rock collection.

DEMONSTRATION: HOW DOES HEATING A MATERIAL CHANGE IT?

What to use: Sulfur, test tube, holder, burner, water glass.

What to do: Fill the test tube about a third full of sulfur. Heat it until it is melted and pours easily.

Pour about half the melted sulfur into cold water. Observe it, and compare its appearance with that of the original sulfur. Pour the rest of the sulfur on a piece of cardboard or paper, and let it cool. Set both samples aside and examine them after a day and again after two days.

What was observed: How did the appearance of the sulfur change? Could you see any crystals in the sulfur at any time?

What was learned: Does the condition of a material depend upon how much energy it contains? Does your conclusion apply to all materials or only to sulfur?

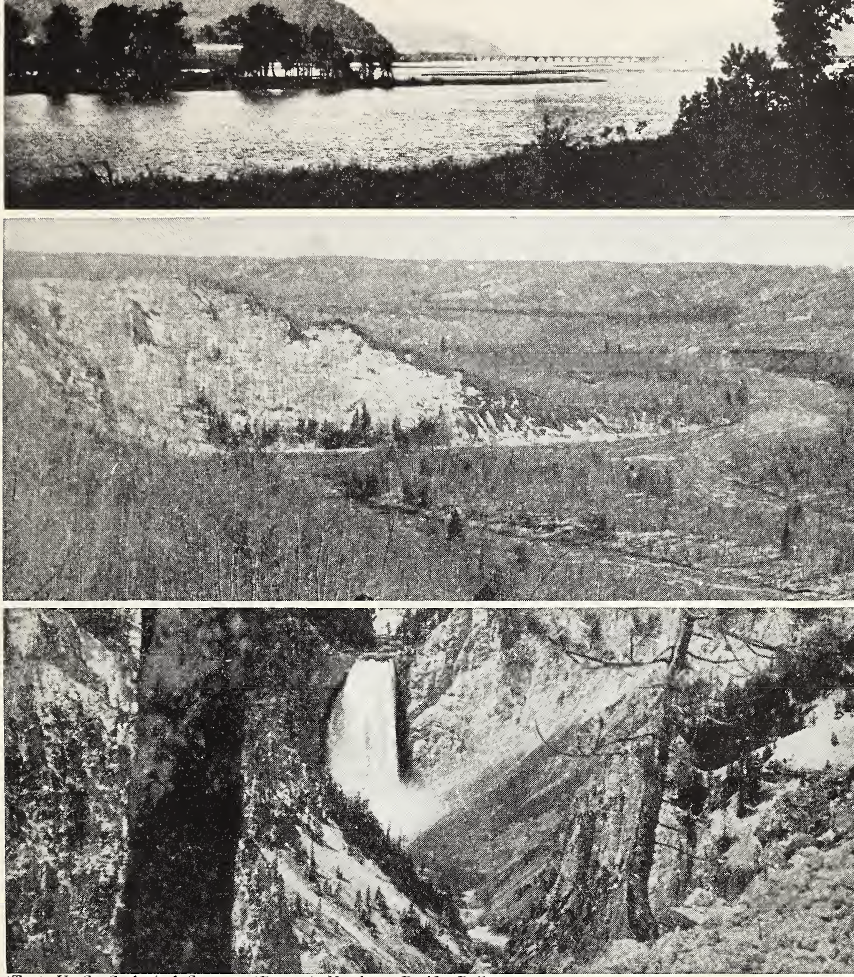
Exercise

Complete these sentences:

The interior of the earth is probably composed of —1— and —2—. The most abundant element in the earth's crust is —3—. Rocks deposited by water are —4—; those formed by heat are —5—; and those which are changed in form are —6—. Rocks formed by animals often form —7—. Gneiss is a metamorphic form of —8—. The gas given off when acid is put on limestone is —9—.

7. What natural forces change the earth?

You can read about changes in the condition of the earth's surface in the newspaper. Within recent years large chunks of rock have broken from Niagara falls, volcanoes have erupted, earth-



(Top) U. S. Geological Survey. (Bottom) Northern Pacific Railway

The upper valley is the water gap of the Susquehanna, formed by the river cutting its way across mountain ridges. The winding St. Louis River (*center*) is carving its way into one bank and depositing material on the other. In this picture you are looking downstream. The falls of the Yellowstone (*bottom*) are caused by a resistant layer of rock.

quakes have destroyed parts of cities, and floods have carried away valuable farmlands. These spectacular events are only a fraction of the natural changes that are constantly going on. In the past two or three billion years the earth has changed considerably.

What chief forces change the earth? If the earth cooled from

a melted state, the heat it originally held would have the power to produce many changes in the rocks. As the earth cooled, it gradually contracted in size. This contraction may not have been very great, but even slight movements, in comparison with the size of the earth, would be sufficient to cause movements of a few miles up-or-down of the earth's crust. Since most of the land on which people live is less than a mile above sea level, this amount of movement is quite important in forming land.

Gravitation is one of the two forces which cause the movement of the land. As the earth contracts, its surface settles, that is, it is pulled down by gravity. And when any material is lifted, it is gravitation which pulls it down again. Solar energy provides most of the power which lifts materials.

The gravitation of the sun and moon provides some lifting force by causing tides. The surface of the earth is moved upward slightly by the same sort of attraction that causes larger tides in water.

When materials are shifted about on the surface of the earth, its weight changes. A load of lava from a volcano or the thick deposits of materials at the mouth of the river make the earth's crust heavier where they come to rest. A layer of ice in a glacier half a mile thick adds greatly to the weight of the surface rocks. As the crust rocks settle under the added load of materials, surrounding rocks are caused to rise or to move sidewise.

All these forces—contraction, gravitation, solar energy, and tides—cause parts of the surface of the earth to rise and fall. The oceans fill the low areas and the high areas form continents. Even the ocean waters flowing over the low places add their share to causing differences in weight of the earth's crust.

How does weather change the earth? Without weather changes there would be much less change in the surface of the earth than there is. The wind provides energy for many changes. It carries heat from one place to another, and is important in causing temperature changes. And of course wind blows sand and dust around and causes waves which cut the shores of all large bodies of water.

The constant movement of air makes precipitation possible. Where wind bearing water vapor is cooled, the vapor condenses and falls in some form. Rainfall is heaviest in the United States along the Gulf of Mexico and the north part of the west coast. Here the most water is available for changing the earth.

Changes in temperature cause some changes in the earth's surface. When rocks expand and contract they may break, just as cold glass may when put into hot water. Water freezing in cracks and pores of rocks expands and breaks or softens the rock. Freezing also breaks lumps in the soil.

What agents of erosion change the earth? Weather provides the

tools which wear away the earth. But the wearing of the earth would not occur very rapidly unless some places were higher than others. It is where water or ice can move downhill that erosion occurs most rapidly.

No other force changes the earth so much as does running water. A thin layer of soil is washed from every sloping field by every heavy rain. And in mountains and on high plateaus the amount of cutting by running water is almost unbelievable. The mud of the Arkansas, Missouri, and Colorado rivers consists of soil and rock cut from the land by running water.

Running water forms the great valleys and plains where most people live. When land is elevated water immediately starts cutting it down. At first, when the rivers are young, the valleys are steep-sided and have rapids and waterfalls. There usually are lakes not reached by rivers. For thousands of years the newly elevated plateau becomes more rugged as deeper valleys are cut into it. Gradually the sides of the valley are washed down, the hilltops are rounded, and the slope of the river decreases as it wears its bed nearer sea level. The mature river drains the land rapidly and well. In doing so it often causes floods. After hundreds of thousands of years the river may wear the land down to a low, flat plain. When it has hardly enough slope to drain the land it has reached old age.

Every bit of solid material carried from the land by a river in one place is deposited somewhere else. The Great Plains, the Atlantic Coastal Plain, and the land of the Mississippi Valley south of St. Louis consist largely of soil brought by running water from distant mountains. There is a great shelf of rock and soil around every continent made by the settling of soil in the ocean.

There are times when the most important force changing the earth is not running water, but ice. Within the past million years there have been four huge glaciers which covered the northern part of the United States and, of course, the northern part of the earth. The most recent one started melting away only about 25,000 years ago. These great glaciers lasted from 50,000 to more than 100,000 years. They were so huge that they caused the earth to settle beneath their weight and left less water in the oceans than usual. They slid slowly downhill carrying rock and soil with them, and grinding surface rocks into powder. This material was deposited in ridges called moraines along the edges of the glacier, or dropped in irregular hills as the ice melted. The melting glaciers formed great rivers. The almost-dry valleys of two of these ancient rivers are now called the Minnesota Valley and the Grand Coulee. In some places the water from the glacier formed great lakes in which mud settled and formed wide plains.

There have been warm, dry periods, lasting thousands of years,

Trinidad (Colo.) Chamber of Commerce

The crust of the earth is made up of the lighter rocks which form mountains. The stone wall is a dike of igneous rock.

when wind was even more important than it is now in changing the earth. There are many regions where dust-formed hills and plains provide rich soil used for farming. In our own West, wind still is changing the earth. Along many coasts there are areas where sand dunes are moved by the wind.

Do volcanoes change the earth? We have seen very little in our own lifetimes to give us an idea of the changes which may be brought by great outpourings of lava from the earth's interior. Yet lava has covered the land hundreds of feet deep, burning vegetation and making the earth unfit for life. You can find in some western states lava so recently formed that it still looks like fresh cinders from a furnace. Some lava flows form high volcanic mountains, while others form great, rough plateaus. It is possible that equally great changes will occur again.

DEMONSTRATION:
HOW DOES WATER SORT SOIL?

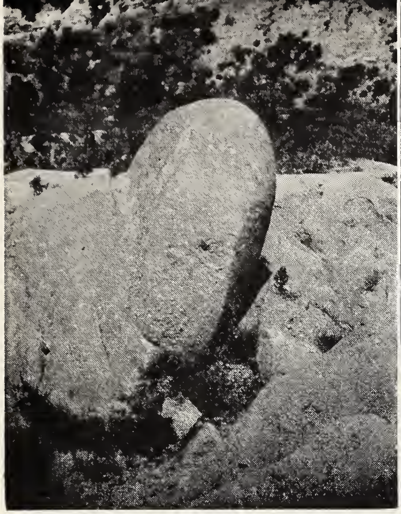
What to use: Three quart jars, soil samples, window screen, watch with second hand.

What to do: Prepare three soil samples. For one, use only materials which will go through the screen. For a second, use only materials which will not go through the screen, being sure that lumps of fine soil are broken. For the third use unsorted materials.

Fill the three jars almost to the top with water. Into each quickly pour a cup of a sample of soil, noting the time that the sample was poured in. Note the time when the first particles reached the bottom. Again note the time when most of the particles large enough to see individually have settled, and again when the water is fairly clear.

What was observed: Were the layers in the unsifted soil clearly marked? What particles settle fastest? Do any float? How long did it require for the coarsest particles to reach bottom?

What was learned: In what order




U. S. Geological Survey, photos by Gilbert

Rocks weather in different ways. The rounded granite rock (*left*) weathered by expansion and contraction; the limestone rock weathered by solution along the cracks.

do soil particles settle? Explain the statement that water-deposited soils and rocks are found in layers.

Exercise

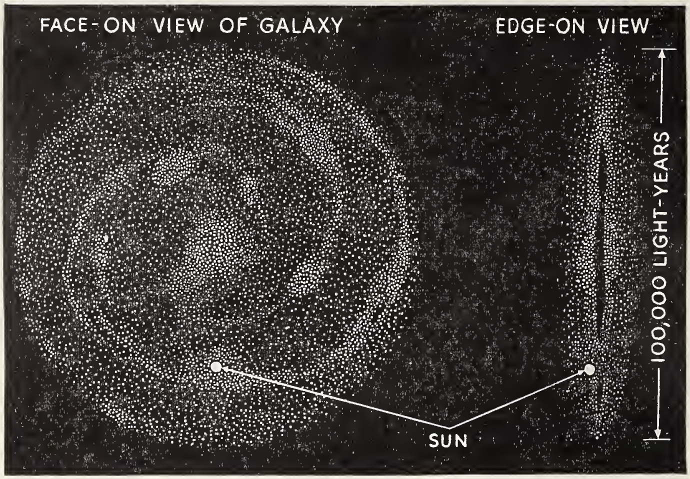
Complete these sentences:

When a material cools it generally —1—. Some shifting of the earth's surface may have resulted from —2— when the earth cooled. When the —3— of the earth's crust is changed by materials moved to new locations, the land —4— beneath the materials and —5— somewhere else. The chief force wearing down elevated lands is —6—. Glacial materials are deposited in ridges along the —7— of the ice and in irregular hills when the glacier —8—. Ice-deposited hills are called —9—. A —10— river has steep banks and rapids, a —11— river has gently sloping banks and good drainage, while an —12— river barely drains the land.

8. How does the sun provide energy?

The energy of the sun is given off in all directions. Most of it probably does not strike anything but, like the light of the other stars, goes on and on. It is almost certain that the bodies in the solar system—the planets, their moons, the asteroids—are the only ones which receive much energy from the sun. In proportion to the space around them, these bodies absorb a very small portion of the total energy given off by the sun.

Where does the sun get its energy? There have been many hypotheses about the source of the sun's energy. Some have been based upon the idea that the material of the sun is on fire. Others have been based upon the idea that the sun is shrinking, and as the molecules fall inward, they give off their energy in the form



This diagram provides an approximate idea of the shape of the galaxy of which the sun is a star. The sun, of course, is not the largest star but is shown large in order to locate it.

of heat. These ideas are not sound, however.

The present theory is that the energy of the sun comes from changes in the nature of atoms. Whenever matter is in balance, its energy is kept within the atom. But when some unusual condition exists, atoms may be combined or broken up. This unusual condition which exists on stars and not on the earth is an enormously high temperature. For the 10,000-degree temperature of the sun is only the temperature of the surface. Inside the sun the temperature is much higher than that.

As a result of its giving off energy, the sun is gradually losing its mass. This is a matter of no immediate concern, for the process seems to have been going on for perhaps two or three billion years and will probably continue for many more billions of years before the energy of the sun becomes too small in amount to warm the earth.

What kind of energy does the sun give off? It is probable that every type of radiation from cosmic rays to radio waves is produced by the sun. But many of these—particularly the shorter waves—do not reach the earth in amounts of which we are conscious. We are aware of the light of the sun, of the invisible but burning ultraviolet rays, and of the equally invisible but longer infrared or heat rays.

The light which strikes the upper atmosphere of the earth is not the same light which we see. The blueness of the sky shows that the blue rays are scattered by the gases and other materials of


Yerkes Observatory

This great spiral nebula is 930,000 light-years distant. It is a galaxy composed of billions of stars.

the air. The still shorter ultraviolet rays are absorbed so that many of them do not reach us at all. If they did, life would not exist in its present form, for some of these filtered-out, ultraviolet rays are deadly to most living things. The red and yellow light reaches the earth without much scattering, a fact which explains the yellow color of sunlight.

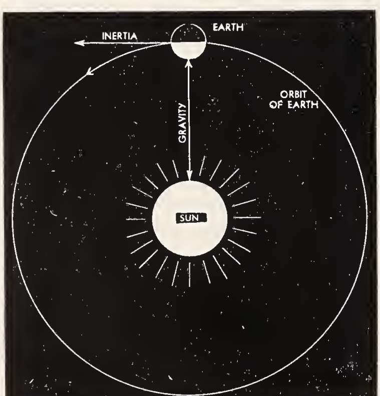
Neither the amount nor the type of energy given off by the sun is always the same. Sometimes the huge sunspots, which are cool areas (about 7000 degrees Fahrenheit), pass across the face of the sun in larger than usual numbers. During this time the sun gives off less heat and more radiation of other types. The sunspot is a severe storm of gases carrying huge electrical charges. Magnetic waves are set up as a result, and telegraph, radio, and telephone communication is upset. Yet on the average, there is little difference in the amounts of solar energy received by the earth from day to day.

The amount of heat that strikes the planets is dependent upon their distance from the sun and upon their size. The intensity of light or any other form of radiant energy decreases in proportion to the square of the distance from the source. That is, since Jupiter is five times as far from the sun as is the earth,

on each square foot of Jupiter there falls only one twenty-fifth as much energy as falls upon a similar area on the earth. Mercury, which is about four-tenths as far from the sun as is the earth, receives more than six times as much energy from solar radiation. Venus receives about four times as much energy as does the earth. Venus, however, is cloud-covered and reflects more of its light than does the earth, so that it retains only about 1.4 times as much energy as the earth's surface retains. Mars receives radiation from the sun of less than half the intensity of that received by the earth.

Thus we see that the actual temperature of a planet's surface may depend upon factors other than its distance from the sun, which is the most important factor.

What controls the motion of the planets? The planets revolve in nearly-circular orbits around the sun. Two forces cause them to do this. One force is that of the sun's gravity.



The earth moves along in its orbit because of inertia and stays in it because of the gravitation of the sun.

The law of gravity is stated thus: Every body in the universe attracts every other body in proportion to its mass and inversely in proportion to the square of the distance between them. That is, the force of gravity becomes less with the distance, just as the intensity of light does.

For any object, the earth for example, to revolve in a curved path, another force besides gravity must act at the same time. All planets move through space at a considerable speed. If the planets had been hanging motionless in space instead of being in motion, they would have started falling immediately toward the sun until they crashed into it.

The true explanation of the motion of the planets is centrifugal [sĕn·trĭf′ū·găl] force. Recalling the familiar stone-whirled-at-the-end-of-a-string experiment, you know that the force exerted by the string must be enough to keep the stone from breaking loose, and that the speed of the stone must be enough to keep the string tight. Gravity provides the "string," and the motion of the planets provides the speed.

The nearer planets are pulled with much greater force toward the sun than are the outer planets. To offset this pull, the inner planets must move at much greater speeds than do the outer planets, to keep from falling into the sun.

DEMONSTRATION:
DO ELEMENTS GIVE OFF LIGHT
OF DIFFERENT COLORS?

What to use: Bunsen burner; iron wire; sandpaper; salts of copper, sodium, potassium, cobalt.

What to do: Polish the iron wire, moisten it, and dip it into one of the salts. Hold the salt in the hottest part of the flame. Observe its color. Repeat with the other salts.

What was observed: Make a table of your results.

What was learned: Answer the question at the beginning of the experiment, insofar as the evidence you have permits you to do so. How does this information help us to understand the stars?

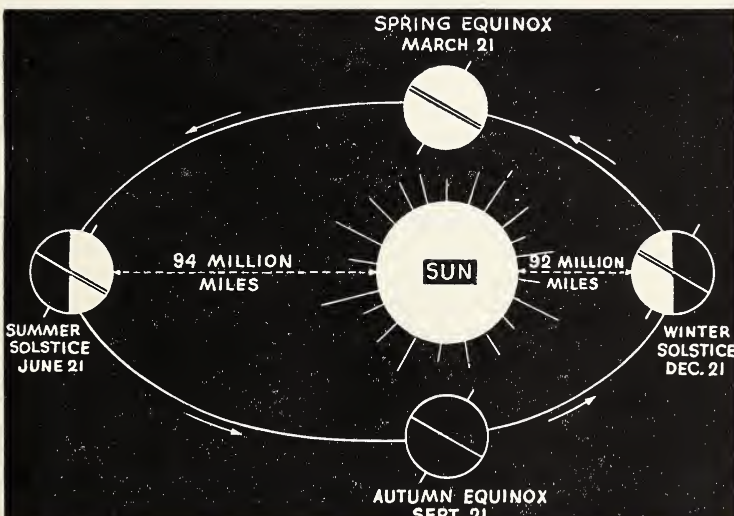
Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: atom; mass; 10,000; radiant; sunspot; ultraviolet; magnetic; square; heat; speed; gravitation.

9. Why does solar energy vary in amount?

We can understand better the effect of solar energy upon the changing surface of the earth if we understand the causes of variations in the amount of energy falling on the earth. The amount of solar radiation received by the earth is called insolation.

Does the angle of the sun's rays affect the earth's energy supply? The greatest amount of radiant energy is absorbed by a surface at



The changing angle of the earth's axis in relation to the sun is the chief cause of changes in seasons. In this drawing the off-center position of the sun is greatly exaggerated. The dates are approximate.

right angles to the rays. As the angle becomes less, the amount of energy falling upon a unit of area also becomes less.

There are three factors which determine the angle of the sun's rays at any given place at a given instant. These are the latitude, the time of day, and the season. To a very minor extent the slope of the land may be considered a fourth factor. At any instant there can be but one point on the earth's surface where the sun is directly overhead. This point receives the greatest amount of energy from the sun.

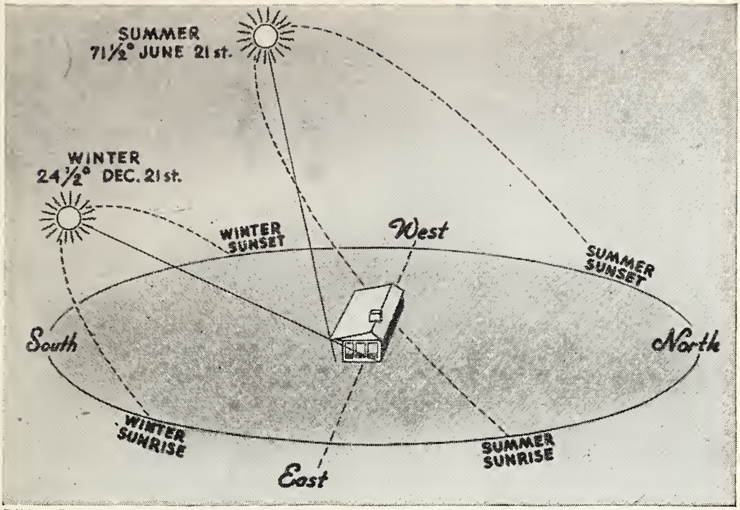
The latitude of a given place determines the average amount of solar energy which falls upon it compared to places farther north or farther south. It is estimated that at the poles only 38 per cent as much solar energy falls during the year as at the equator. At latitude 60 degrees the amount of solar energy is about 58 per cent of that falling on the equator. At latitude 40 degrees (which is the latitude of southern Pennsylvania) the earth receives 79 per cent as much energy as falls at the equator. At latitude 20 the amount of energy is 94 per cent as much as that of equatorial regions.

During part of each year the polar regions receive no solar radiation at all. For, as you know, the earth's axis is inclined at an angle of 23½ degrees from the perpendicular. As the earth revolves around the sun, first one pole and then the other is inclined away from the sun. Except for a few moments on March 21 and on September 22, one pole is always in darkness. On the other hand, each pole in turn is inclined toward the sun during its summer season and receives considerable amounts of solar energy during this time.

The earth's rotation and inclination also affect the length of day and night. Although only one-half the earth can be lighted at any one time, inclination and rotation cause the days to be long in the summer months and short in the winter months. Thus there are greater differences in temperature at a given place than there would be if days and nights were always of the same length.

Is our distance from the sun always the same? The distance from the sun to the earth is about two million miles greater in northern summer than in winter. This makes our winters shorter and warmer and our summers shorter and cooler than they would otherwise be. It is estimated that the northern winters may average as much as six degrees Fahrenheit warmer than they would be if we had winter when the earth was farthest from the sun.

Does the earth always absorb solar energy evenly? The amount of energy from the sun received during any given day depends in part upon the amount that is reflected into space and upon the distance over which the heat is scattered. It is estimated that more than a third of the energy which might fall on the



Libbey-Owens-Ford Glass Company

The angle of the sun above the horizon changes with the seasons. In the latitude of Chicago summer sun would not shine into the house at noon, but the winter sun would shine far into the rooms.

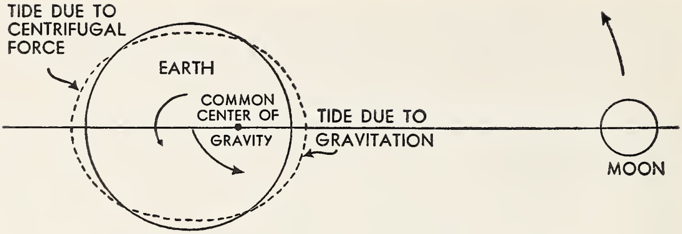
earth is reflected before it ever reaches the ground.

The chief reflectors of solar energy are clouds. It is a common experience to note the cooling effect of a cloud passing over the sun on a partly cloudy day. Volcanic dust also affects heat absorption, but it is not known exactly what the effect is.

The type of surface on which solar energy falls also affects the earth's ability to absorb heat. Ice, sand, black soil, grass sod, and forests each absorb varying amounts of heat, causing considerable local differences in temperature.

Does the sun always give off the same amount of energy? It has been impossible to observe the sun for a long enough time to know whether it varies greatly in brightness from one million-year period to another. But it is known that sun spots make a difference in the amount of heat the sun gives off. When sunspots are most abundant, it is estimated that the loss of heat is about 2 per cent of what would normally fall if there were no sunspots. This difference is enough to cause rainy seasons when there are many sunspots.

Are there long-time changes in earth temperature? One of the great unexplained mysteries of the earth is what causes the changes in temperature which permit it to go through long periods of glaciation. These have occurred since the earliest eras. There still remain five-million



The tide on the side of the earth toward the moon is caused by gravity, while that on the opposite side is caused by centrifugal force.

cubic miles of ice around the North and South Poles.

If we add together the most recent glacial ages, the four glaciers together lasted about 350,000 years. During the last million years the earth has had large glaciers for about one-third of the time.

Several hypotheses have been advanced to explain the formation of glaciers. One is that volcanic dust in the air may cause changes in temperature sufficient to make deposits of ice possible, for rather slight changes in temperature cause considerable differences in climate. It is well known that after volcanic explosions of the type which fill the air with dust, winters are colder and summers are shorter. Another hypotheses is that the solar system passes through very thin clouds of dust in space.

In order that glaciers may form, there must be heat enough to continue evaporation of water from the oceans, or no snow would fall. It is not absolutely certain, in fact, that glaciation is not caused by unusual warm instead of unusually cold periods.

Do tree rings record climate changes? Variations in climate can be estimated by studying tree rings. The thickness of the annual rings of growth of trees corresponds quite closely to the suitability of growing conditions of a given year. To measure these rings, thin slices are cut from the stem of a tree and their images projected upon a screen to enlarge them. The differences in thickness of the rings indicate differences in climate. Since some trees are hundreds of years old, it is possible to trace climate far into the past. Then by matching rings with ancient wood samples, it is possible to continue the history still farther.

The present indication is that the earth is growing somewhat warmer and drier than it was a few hundred years ago.

Do all parts of the earth hold heat equally well? As you know, the temperature of land and water differ, although both may be at the same latitude and receive the same amount of insolation. Water, because it holds several times as much heat as an equal weight of rock, warms and cools

more slowly than does the earth.

Although clouds reduce the amount of heat reaching the earth, they also reduce the rate of heat loss. As you have observed, the earth cools more rapidly on a clear night than on a cloudy night. Heat losses at night from deserts are much greater than from the moist farm lands of the Middle West.

Mountainous regions lose heat rapidly because they are protected by only a thin layer of air, and as a result radiation of heat into space is more rapid than it is in lower regions.

DEMONSTRATION: DOES WATER HOLD MORE HEAT THAN IRON DOES?

What to use: Balance, beakers, piece of sheet iron, burner, thermometer.

What to do: Cut a strip of sheet iron, and roll it to a size that will fit easily in a beaker. Weigh the iron. Put the iron in a beaker of water, and bring the water to a boil. Prepare two beakers of cold water containing equal weights of water at the same temperature. Record the temperature. Put the iron in one beaker. In the other pour boiling water equal in weight to the iron. Measure the temperatures of the water in the beakers as soon as they have reached a stable temperature.

What was observed: Compare the increases in temperature of water in the two beakers.

What was learned: How does the amount of heat held by water compare to the amount held by iron? What errors did you leave uncorrected in your experiment?

Exercise

Complete these sentences:

Three factors affecting the angle of the sun's rays on the earth are —1—, —2—, and —3—. The exposure of the earth to the rays of the sun is called —4—. The amount of solar energy falling on the earth at latitude 50 is probably about —5— per cent as much as at the equator. The winters of the southern hemisphere are —6— than they would be if the earth were always equally distant from the sun. The earth absorbs about —7— of the insolation it receives. The —8— of the sun reduce the amount of insolation. The first of the four recent glaciers appeared about —9— years ago, and the most recent began to disappear about —10— years ago.

10. Is the universe changing?

There is no way of knowing how big the universe is, nor whether it is changing in size, nor how old it is. Nevertheless, these are interesting problems, and many scientists are studying them.

Scientists know that the universe is changing, for everything in it is in motion. Even as they observe, some stars change in brightness. The length of time these changes have gone on is estimated in several ways. One way is from the study of the stars. Another is by study of radioactive compounds—those which give off energy as their atoms break


New York State Museum

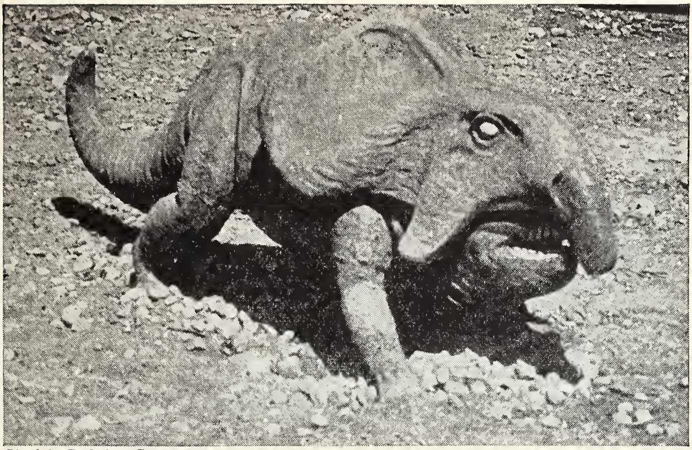
The rocks themselves carry a record of how they were formed. The fossil shells in this rock give the geologist ample information for determining its history.

up. A third is study of the earth, for it is believed that the materials of the earth are about as old as the rest of the universe.

What is the universe? The universe includes, in addition to the sun, all the other stars and all space. Space extends, for practical purposes, as far as there are any stars, and as far as any form of energy from any star may extend.

Scattered throughout the universe are many clusters of stars which, compared to the general emptiness of space, are fairly close together. These groups of stars are called galaxies. In our own galaxy, according to reasonable estimates, there are at least 30 billion stars and possibly more than 100 billion. As you know, not more than 2500 of these stars are ordinarily visible at one time. The rest can either be seen by use of powerful telescopes, or their presence can be estimated by other means. Some of these stars are very hot and blue in color, some are cooler and red, and others are of varying temperatures and colors in-between. They form a group shaped roughly like a magnifying glass. This star system is perhaps 3000 to 10,000 light-years thick, and 30,000 to 200,000 light-years across (a light-year is six trillion miles). Looking out into space from the earth, we see part of this group of stars edgewise as the Milky Way.

Stars vary greatly from each



Sinclair Refining Company

This big-nosed reptile, one of the dinosaurs, lived in the period of intermediate life. The one shown here is only a model. This dinosaur was about as big as a pig.

other in size, because some are composed of gases almost as thin as the gases remaining in a vacuum made by the usual laboratory pump. Others are considerably denser than gold. The sun is about 1.4 times denser than water. Because of differences in density, the largest stars may be as much as 100 million times as great in volume as the smallest. But the heaviest stars probably do not weigh more than 100 times as much as the lightest.

The surface temperature of the sun, about 10,000 degrees Fahrenheit, is about twice as high as would be required to change the materials found on the earth into gases. It is entirely probable, then, that the materials of the sun and most other stars are gases. The ordinary expectation is that these hot gases would immediately expand to form a larger star. This is exactly what would happen if the sun were not so large. As it is, its gravity is sufficient to hold these gases fairly well in place.

How old is the universe? As far as is now known, matter and energy cannot be created or destroyed. If this is true, the materials of the universe seem to have been undergoing changes, which are still in progress, for two or three billion years.

One hypothesis about the length of time that the present condition of the universe has lasted has been worked out by complex mathematics. According to this hypothesis, all the matter and energy of the universe were once stored in a dense gas made up entirely of neutrons. Eventually these neutrons started to

break up into electrons and protons and to form atoms. In a reaction resembling the explosion of a huge atomic bomb, elements were formed and some of the stored energy was released. With the formation of free matter and energy, the various galaxies formed, and the whole universe started expanding, just as the materials formed in an ordinary explosion expand. This is only one of several hypotheses which have been developed, and its proof awaits further study.

How do we estimate the age of the earth? Because the earth is near at hand, we can estimate its age better than we can that of the whole universe.

It has been found that rocks deposited at the same time and in the same general area contain similar fossils. The use of fossils as a method of dating the rocks is now universally accepted as a satisfactory method of determining the *order* in which rocks were formed.

To estimate the *age* of the rocks, decomposition of uranium is measured. Uranium decomposes to form helium and lead. Half the uranium changes to lead in about five billion years. By measuring the amount of lead and uranium in a given deposit, it is possible to know when that particular deposit was formed. To do this, it is necessary to find unweathered rock, for if part of the lead or uranium is washed away, the result will not be accurate.

The history of the earth is divided into five huge periods of time called *eras*. These in turn are further divided into shorter periods. Changes in the type of life on the earth apparently resulted from changes in the earth's surface. The earth's crust is marked by two distinct formations: huge ridges which form the continents and huge basins which form the oceans. It seems probable that the ocean deeps have never been land. But there have been many changes in the levels of the continents. At different times there have been shallow seas where there are now mountains, and where once mountains existed there are now lowlands. Each of the five eras is marked by a rather striking shift in the elevation of portions of the continental ridges. The table summarizes some of the important developments of each of the five eras which make up the history of the earth.

DEMONSTRATION: WHAT ARE FOSSILS?

What to use: Functional collection —fossils.

What to do: Using the information which accompanies the collection of fossils, learn what the different types of fossils are.

What was observed: Draw sketches of two or three fossils, and write notes as to their formation.

What was learned: List as many kinds of fossils as you can.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: hy-

pothesis, universe, galaxy, uranium, fossils, one-celled, insects, worms, reptiles, mammals, flowers, ferns, seed plants, recent, early, most primitive, intermediate, ancient, era order.

NAME OF ERA	HOW MANY YEARS AGO DID IT START	CHIEF NEW PLANTS	CHIEF NEW ANIMALS
Cenozoic (recent) . . . . **sē′nô·zō′ĭk**	**60 million**	**Seed plants, as grasses, flowering plants, and trees**	**Man, other mammals; birds**
Mesozoic (intermediate) . . . **mĕs′ô·zō′ĭk**	**190 million**	**Cone-bearing trees, cycads; simple flowering plants**	**Reptiles, as dinosaurs and turtles; small mammals and birds**
Paleozoic (ancient) . . . . **pā′lê·ô·zō′ĭk**	**490 million**	**Ferns; horsetails; mosses; club mosses**	**Amphibians; fishes; mollusks; insects; spiders; crabs; starfish; true worms**
Proterozoic (early) . . . . **prŏt′ẽr·ô·zō′ĭk**	**More than a billion**	**Algae**	**Simple, many-celled animals**
Archeozoic (most primitive) **är′kê·ô·zō′ĭk**	**Two or three billion**	**One-celled forms**	**Many-celled forms**

A review of the chapter

Everything in the universe is composed of either matter or energy or both together. The universe is vast, being made up of many great clusters or galaxies of stars. The sun, which is the center of the solar system, is a star. The earth is one of the planets of the solar system. All matter in the universe is made up of the same particles of energy, electrons, protons, and neutrons. These combine in various amounts to make up the atoms, which are the smallest parts of elements. Atoms combine to form molecules, which are the smallest parts of compounds. Most of the common things around us are chemical compounds.

We can change matter either physically or chemically. A chemical change produces a new substance, while a physical change produces a new condition or position of a substance. Energy is required to produce any kind of change. Some changes give off energy which we can use. Most of the energy available on the earth originally came from the sun.

Air, water, and the many materials of the earth's crust are familiar forms of matter. The earth is the source of all materials we use to serve our many needs. All materials are affected by or related to energy in some way. Weather, which is caused by energy changes, exerts its influence upon the rocks and in various ways upon man's activities.

Word list for study

elastic	sunspot	ore	proton
property	planet	precipitation	electron
state	molecule	erosion	radiant
detergent	centigrade	orbit	chemical
atom	acid	universe	igneous
inertia	nucleus	compound	sedimentary
mass	neutron	formula	metamorphic
infrared	solar	solvent	centrifugal
base	ultraviolet	symbol	galaxy
contraction			

An exercise in thinking

Write the numbers from 1 to 36 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Matter and energy may be transformed, but cannot be created or destroyed.

B. The sun provides the energy which produces changes in materials which make up the earth.

C. When a substance dissolves, its molecules are held in spaces between the molecules of the solvent.

D. A gas exerts pressure upon a surface in proportion to the force and number of molecules striking the surface.

E. All forms of radiant energy travel in straight lines through space.

F. The gravitational pull of one object upon another is in proportion to the mass and inversely in proportion to the square of the distance between them.

G. The more nearly vertical the rays of radiant energy falling upon a surface, the greater the amount of heat received by the surface.

H. Various forces tend to elevate portions of the earth's crust.

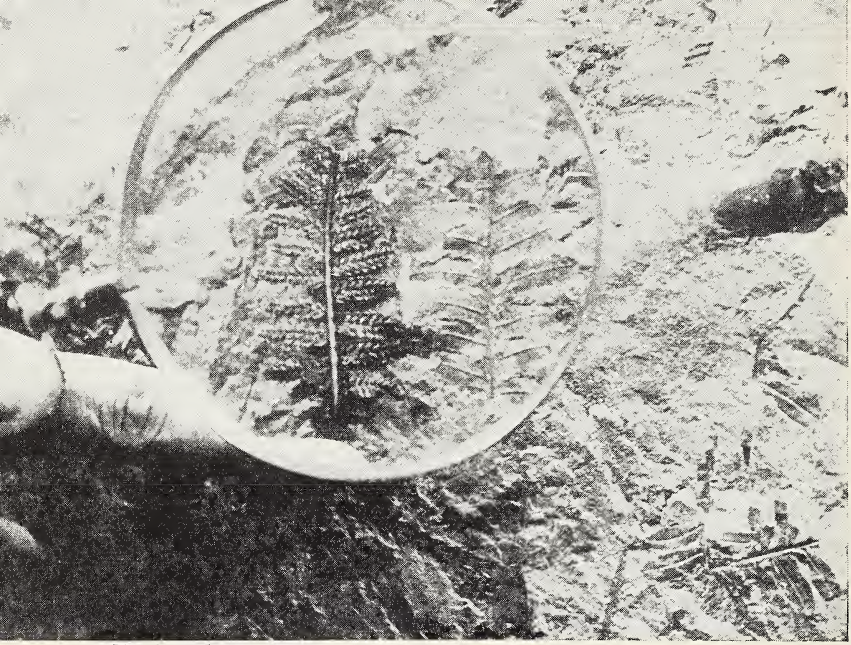
I. The order of fossils in rocks shows a progressive series from simple to complex life, in order of time.

List of related ideas

1. Warming a gas in a closed container increases its pressure.
2. Contraction and settling of rocks in one place causes rocks

to be elevated in other places.

3. Infrared rays travel from a hot iron but are invisible.
4. Life developed on the earth as living conditions improved for some types of plants and animals.
5. There are seasonal variations in heat in most regions.
6. The energy we obtain from burning coal was originally stored by plants.
7. When carbon and oxygen unite, the carbon dioxide formed weighs just as much as the original materials.
8. Objects fall toward the center of the earth.
9. Sugar disappears in tea.
10. When an atom breaks up it changes to energy and to other forms of matter.
11. The sun causes water and air to be lifted against the force of gravity.
12. Water will not dissolve a material it cannot wet.
13. The Colorado Plateau is made up of water-formed sedimentary rocks.
14. The side toward an open fire feels warmer.
15. Certain fossils called index fossils are used to identify rocks belonging to certain ages.
16. The ground usually receives more heat at noon than in late afternoon.
17. Air pressure is about half as much at an elevation of three and one-half miles as at sea level.
18. The moon pulls harder on the earth in causing tides than the sun does.
19. The most ancient evidences of life on earth are carbon streaks in rocks.
20. The energy of running water was stored in the water when it evaporated.
21. Sea-level air pressure is about 14.7 pounds per square inch.
22. When a house is destroyed by fire, the matter of which it was made continues to exist in other forms.
23. The hottest places on the earth are those where the sun is most directly overhead.
24. The earth is held in its course around the sun in spite of the tendency of all objects to move in straight lines.
25. When a solution holds all the salt it can, adding more salt causes some to settle out.
26. Light rocks tend to rise and heavy rocks to sink in the earth's crust.
27. The energy of the sun travels through almost empty space.
28. Dinosaur skeletons are found in rocks not more than 300 million years old.
29. Sedimentary rocks are made of materials loosened by erosion.
30. A gas contracts when its molecules lose energy by cooling.
31. When a fuel is burned in a closed container, the burning produces no change in the weight of the container and its contents.
32. The amount of energy obtained from a hot object is in proportion to the square of the distance from the object.
33. Latitude is the most important factor determining climate.
34. An object weighs less on the moon than on the earth.
35. Soda pop contains carbon dioxide.
36. If the earth's crust did not move, its surface would eventually become a low plain or would be covered by water.



Bituminous Coal Institute

You may need to go no farther than to your coal bin to find fossil ferns.

Some things to explain

1. If the sun should instantly become cold, would we know it at the same instant?
2. Explain how your energy used in running comes from the sun.
3. Why do we say that we live in the age of metals?
4. Do you think that we can soon say that we live in an age of synthetic chemicals? Why can we?
5. What is the difference between temperature and heat?
6. If you find a deposit of fossils in your community, what would be the best way to insure its proper study?
7. Is there any real evidence that the earth is as old as is claimed?

Some good books to read

Collins, A. F., *Boy Chemist*
Compton's Pictured Encyclopedia
Foster, W., *Romance of Chemistry*
Hecht, S., *Explaining the Atom*
Hornung, J. L. and McGinnis, G. C., *Open Door to Chemistry*
Jaffe, B., *New World of Chemistry*
Life, August 22, 1945
Meyer, J. S., *Picture Book of Molecules and Atoms*
Morgan, A. P., *Getting Acquainted with Chemistry*

CHAPTER

2

Conservation of Natural Resources

Our country is beautiful and rich and a wonderful place in which to live. Subject only to the limits of our ability to produce and distribute material resources, there is enough of all needed goods for everyone to live in comfort and good health. We have more material things than did our ancestors, not because more natural resources exist now, but because we make better use of the things that do exist.

Thoughtful people are anxious to keep the world a good place in which to live. In order to do this we must conserve the material things which we need for comfortable living. You are familiar in a general way with the story of how we are using many things either without replacing them or more rapidly than they can be replaced. Our ancestors, lacking knowledge, often wasted things which we would like to have for our own use. It would be cheaper for us to have good houses if more forests were available. It would be an interesting experience to see wild animals in these forests. We would like to be certain that people can continue to obtain gasoline for automobiles in the years to come.

We have today an opportunity to do our share to keep the supply of material resources available for the people of the future, as well as for ourselves.

Some activities to do

1. How much gas does baking powder give off? Devise a method of measuring the gas given off when a measured amount of baking powder is put into water. You may compare various brands in this test.

2. Are common materials acid or alkaline? Obtain litmus paper and test as many common materials as you can. Report your results.

3. Does oil mix with water? Obtain some vegetable oil and samples of soapless detergents and soap preparations. Mix the cleaning chemicals with water according to directions. Put half an inch of oil and half a test tube of water containing suds into a test tube or slender pickle bottle. Shake the mixture vigorously, and ob-

Swift and Company

In the past the natural richness of much of our soil has made possible abundant crop yields. Today we are faced with the necessity of maintaining our natural resources.

serve how much oil remains free and how much mixes into the emulsion.

4. Repeat this experiment, using cleaning fluids instead of water.

5. Make a collection of fuels, obtaining as many kinds as you can. Arrange them neatly with proper labels on a board for display.

6. Make a collection of several kinds of metals and alloys. Learn their names and properties.

7. Make a collection of several kinds of plastics. Learn their names and properties.

8. Make a permanent collection for the school of samples of rock and soil taken from newly dug wells. The location of each well and the depth at which the sample was obtained are information essential to make the collection of value.

9. Make a model bellows and forge. Use leather for the valves, and rubber sheeting or plastic cloth for the sides of the bellows. Use a flowerpot for the fuel container. You can obtain a very hot fire if you make the model properly.

10. Put samples of sand, clay, and humus into lamp chimneys closed at the bottom with cloth held in place with rubber bands. Weigh each. Stand the lamp chimneys in a pan of water. Observe which absorbs the water fastest. When the samples are saturated, again weigh each lamp chimney.

11. Put samples of the soil under the microscope and observe them.

12. Heat a sample of humus soil in the crucible, and observe changes which take place in it. If a delicate balance is available, weigh the sample before and after heating it.

13. Examine poorly built and good pieces of equipment in order to compare their design and materials. Report on the differences you find.

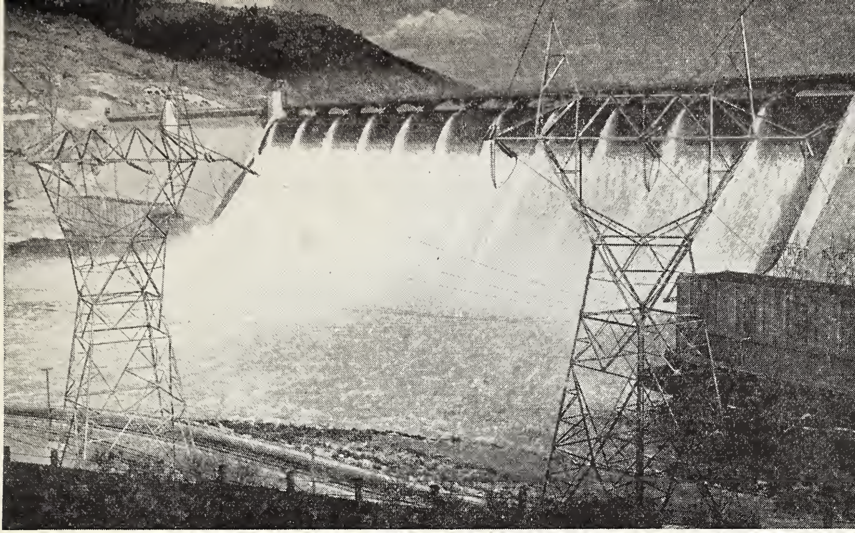
Some subjects for reports

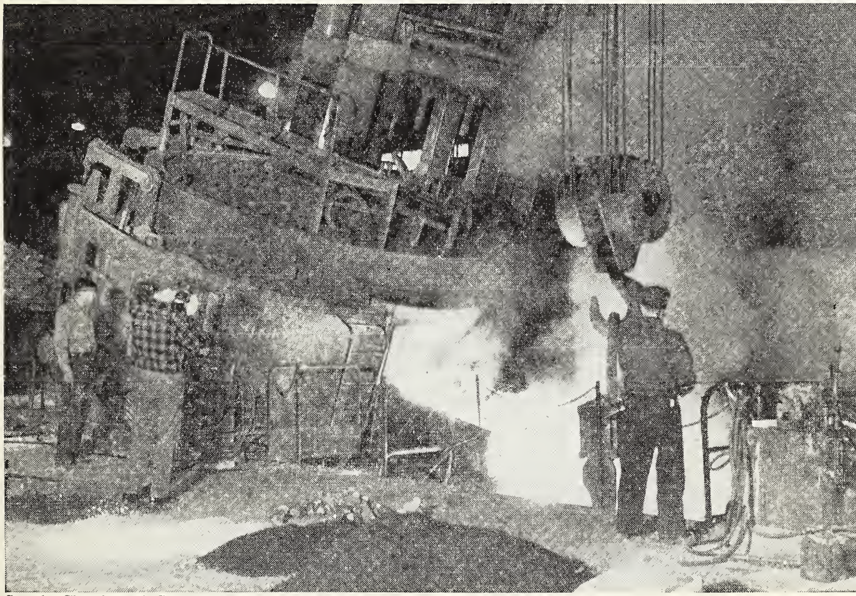
1. Water-power resources of your state and their development

2. Wind-electric generating plants

3. The development of atomic energy

4. Uses of waste paper collected in school projects





Seattle Chamber of Commerce

The electric power generated at Grand Coulee Dam is used in an electric arc furnace to refine steel, thus saving irreplacable coal.

5. Mineral resources of your state and their development

6. Materials used in paints and varnishes and other finishes

7. Types of soil found in your neighborhood

1. Is conservation really necessary?

Our existence depends upon maintaining a sufficient supply of foods, fuels, and other sources of matter and energy. We have learned that we have no ability to create matter and energy, but can only change what is available to suit our needs.

What is conservation? Conservation is a complex process of saving some materials, of using wisely what we must use, and of replacing used materials insofar as is possible. It applies to soil, to minerals, to water, to wildlife, to forests, and to all the natural things which exist on the earth.

To understand the problem better, we can classify materials as replaceable or irreplaceable. For example, sunshine is replaceable. All of its energy will be lost eventually into space after being absorbed by the earth. But there is a fairly constant supply of heat from the sun to replace what is lost.

Water flowing downstream in a river is also replaceable. The flow of a river from lakes and wooded mountains will remain about the same from year to year. Any energy which is not taken from running water is lost for our use. Similarly wind which blows without doing work is a wasted source of energy.

Coal, on the other hand, is irreplaceable under practical conditions. We can use the coal supply rapidly, but it requires hundreds of thousands of years and conditions which do not exist extensively on the earth today for coal to form.

Forests are replaceable if trees are cut only as they mature, and the soil is protected. But if the soil is left bare or is damaged by fire, forests will not replace themselves.

The wise use of natural resources is not easily determined. If we build a dam across a river in order to use the energy of water power, the lake formed will cover land useful for farming or for growing forests. The release of water from storage lakes for irrigation or navigation causes changes in the level of the lakes, which kills some trees along the shore, and some of the water plants and animals in the lakes. On the other hand, a lake with a constant level favors the growth of some forms of wildlife.

One of our most important resources is the soil. It may be replaceable if properly managed, but may be so damaged within a few years that it cannot be restored to its original fertility for hundreds of years.

Have we lost important natural resources? When white men first came to the United States, the average depth of topsoil was nine inches. Today this depth is about six inches. One-fifth of the land which once would grow crops is no longer fit for that purpose. The best iron ore in the Great Lakes iron mines is nearly gone, and the great Montana copper deposits are largely used. A

large portion of the oil supply has been used.

There are some vital materials which have never been found in the United States in important amounts. Among these are tin, mercury, tungsten, and uranium. These may be obtained only by trading other natural resources with other countries.

Most of the original forest which covered about half the United States is no longer in existence. In the dry West much of the natural grass which grew sparsely on desert land has been so completely destroyed by too many cattle, sheep, and horses grazing that the land is being washed away by the occasional heavy rains which fall in that region. Our water supply is dangerously low. Most western areas are using about all the water that is available. Many eastern cities have had water shortages. Ground water is being used faster than it is replaced. Many rivers are polluted with filth and chemicals.

It is impossible to predict with certainty how long the supply of any given material will last. Rate of use varies as war, depression, and other objectionable activities replace the desirable work of peaceful living and production of goods. We cannot know when substitute materials will be developed to replace those now in use. We cannot be certain as to how much of a given material will be discovered in the future.

With these reservations in mind, it seems that at present

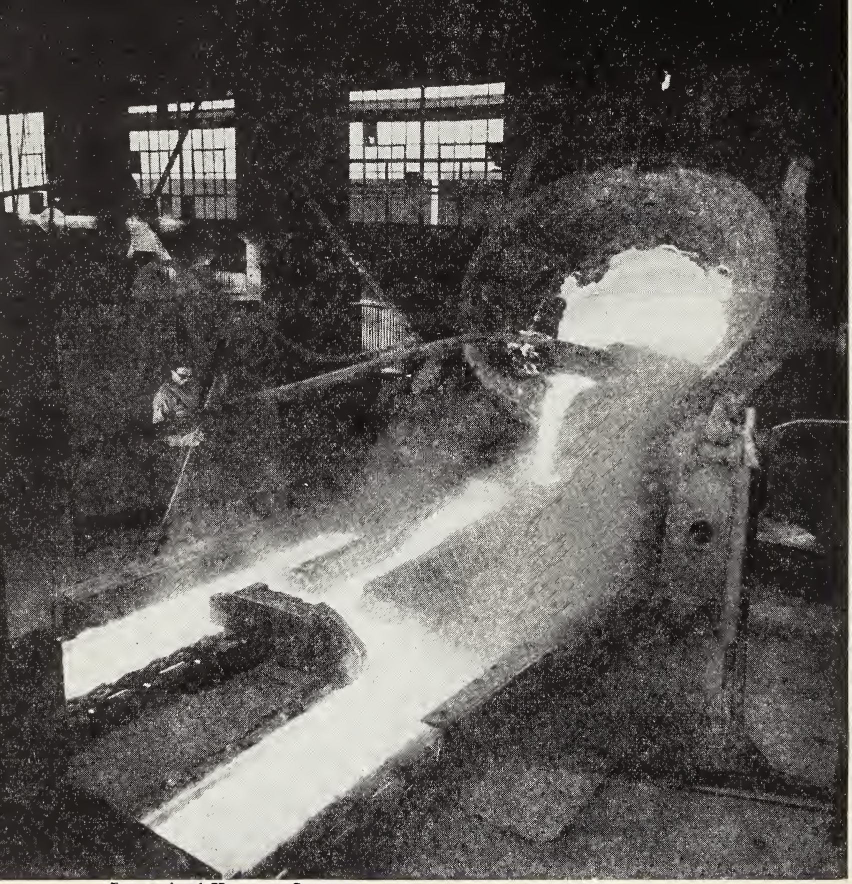
U.S.D.A.

At any point on the surface the depth of the soil is not great. Usually the depth of fertile soil is less than a foot, while the depth of soil of any type is only a few feet.

rates of use our soft coal supply may last about 3000 years, our oil supply 10 to 15 years, and our supply of metals from 10 to several hundred years.

We have inexhaustible sources of iron in low-grade ores, of aluminum in clay, and of magnesium and sodium in ocean water. But so much energy is required to refine these low-grade materials that their use will increase the rate at which our fuel supply is exhausted.

Can we avoid economic waste? There are several forms of waste which can be avoided. We certainly can quit burning forests



International Harvester Company

The melted iron is poured from the ladle into sand molds to form pigs. When the pigs are cooled they are either stored or remelted for further purification.

and grass. We can improve poor soil-cultivation practices. But many forms of waste can be avoided only by educating people to change their wants. It is certainly a waste to produce a worthless article or one which will wear out quickly. Style changes decrease the life of useful articles. Every time the length of dresses changes, the soil of southern cotton fields is affected. Every time there is an increase in smoking cigarettes, more of the good earth passes into smoke, gases, and ash. War is one of the most wasteful of all human activities and must be avoided in this atomic age if people are to survive.

Can we make better use of present materials? The first way

of improving use of materials is to use replaceable materials when possible instead of irreplaceable materials. Water power should be developed and sold at the lowest possible cost to avoid use of coal. Sunshine may be used for heating houses, thus saving coal. Plastics from plant materials may replace metals for many uses.

There are many waste products which may be made useful. Sawdust is today the source of many chemicals. Corn cobs, hulls of grain, cornstalks, pulp and fiber of sugar cane, and many other farm products are sources of materials which can be made useful by chemical change.

Another kind of waste results from throwing away good materials. Some of these materials are not only difficult to dispose of, but could well be re-used. A pop bottle broken on a beach may cause serious injury or death. The same bottle returned, cleaned, and re-used saves our coal supply. Tin cans, bits of scrap iron, copper, gold, and silver, waste paper, old bottles, and old clothing provide materials which can be made into useful products. Old movie film is a source of silver. In Europe and Asia, where more people live in less space and with fewer natural resources, re-use of materials is an accepted practice.

Exercise

Complete these sentences:

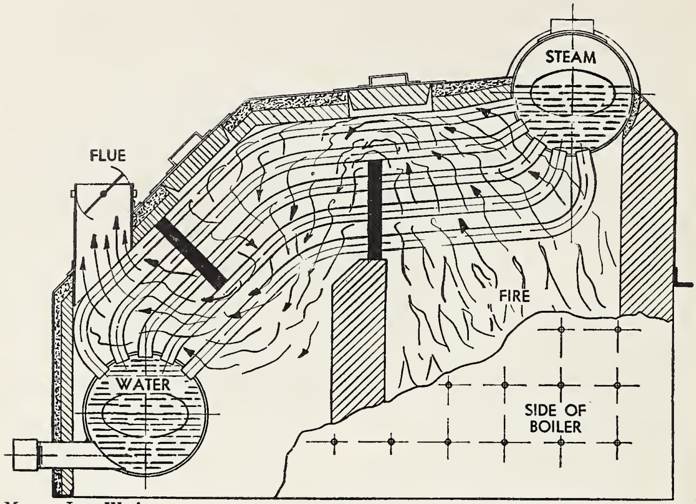
Saving and wise use of materials is —1—. —2— provides energy which is lost if not used. Of our irreplaceable energy sources —3— will probably last the longest. Use of low-grade ores requires use of more —4— to obtain metal. Houses may be heated by —5— which is otherwise lost. No matter what material is used, —6— in some form is required for its production. We have lost about —7— of the thickness of our topsoil, and about —8— of our original farm lands have become unfit for use. In order to obtain power from running water, —9— are generally built in streams.

2. What sources of energy are available?

You are quite familiar with the various materials which will give off energy. However, you need various forms of energy for different uses. Sometimes energy goes through many changes before you are able to use it. We cannot always use energy directly from those things which contain it.

What is our most important energy source? Common, soft coal is the most important single source of controlled energy we have today. More than half the houses in the United States are heated by coal or by coke made from coal. More than half the electricity used is made by machines which obtain their energy from coal. No other material mined from the earth has the value in dollars that soft coal has.

Coal is used for a great variety of things. About one-fifth of the coal mined today is used by rail-



Murray Iron Works

Coal is used to generate steam in a boiler. This type of boiler generates steam for heating and for engines.

roads, another fifth for home heating, another fifth for general manufacturing, and still another fifth for making iron, steel, and coke. More than one-tenth of the coal is used for making electricity. The remaining tenth is used for making chemicals and gas and for a variety of other uses.

In order to obtain energy from coal, it must be burned. For making electricity and operating trains and machines in factories the heat produced is used to produce steam, which in turn is used to operate engines. In home heating plants either air or water may be heated by the burning coal.

In making iron and steel some of the coke formed from coal combines chemically with material from the ore, but again energy is released by chemical change. Even when coal is used to make other chemicals it must be heated by burning coal.

Most coal is wasted by using it inefficiently. Efficiency is found by measuring the amount of energy obtained from a machine, and dividing it by the amount of energy put into the machine. If a piece of coal contains enough energy to lift a hundred pounds of iron one foot and is burned in an engine which will lift only 25 pounds of iron one foot, its efficiency is 25 per cent. A machine is efficient if it wastes very little energy and inefficient if it wastes most of the energy put into it.

Most of the engines which use coal waste from 75 to 90 per cent of the energy of the coal. Stoves and furnaces often waste from 40 to 75 per cent of the energy available. It is likely that we could save two thirds of all fuels now

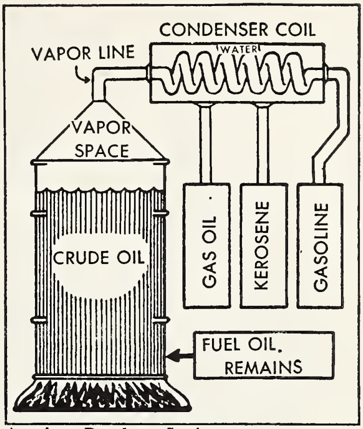
used if we could invent really good stoves and engines.

Another way of making the coal supply last is to use it for making better products. Since about 18 tons of coal are needed to make one four-ton truck, making a truck that would last twice as long as trucks now last would save half the coal used in making such trucks.

What other fuels are available? Three other common fuels are hard coal, gas, and petroleum products. The hard coal is largely used for home heating. Gas is used for both home and factory heating. Petroleum products are used in gasoline and Diesel engines and for heating. About one-fifth of our homes are heated by either gas or fuel oil. Real effort is being made to conserve these fuels. It is necessary to use gas soon after it comes from the ground, for it is too bulky to store. Gas is run through pipes to places where it can be used. In the production of crude oil it is very important to get all possible oil out of the ground. Only 10 to 20 per cent of the underground oil was recovered by early methods of obtaining it. Modern methods have increased yield to obtain 50 to 80 per cent of the possible underground supply.

Gasoline and Diesel oil can be made from coal. A ton of coal will yield about a hundred gallons of these fuel oils.

As is the case with coal, the greatest waste in use of petroleum products is because of poor engines. No gasoline or Diesel engine yields much more than a third of the energy in the fuel, and many of them yield no more than a fifth of this energy.



American Petroleum Institute

The simplest way to refine crude oil is to heat it and to condense the vapors at different temperatures.

Are wind, water, and sun sources of energy? Many people are likely to overestimate the amount of water power available in the United States. Water power is undependable in amount except where lakes or wooded mountain regions control the water supply. During the drier parts of the year there is not enough water power in the United States to provide all the electricity now used. Much of this water power is not where it is needed. However, there should be much greater use of water power than there is. Only about half of the dry-weather power is now developed and used, and only a fraction of the wet-weather power is used. While

Brookhaven National Laboratory

This model of a nuclear power plant shows some of the stages necessary for the production of electric power from atomic energy.

it is expensive to have two kinds of power plants, water should be used in wet seasons and coal only when water is not available. Water may be stored behind dams for later use.

Wind power is expensive to use because large windmills are needed to obtain enough power to be of value. Sun power is also expensive to collect and use. Even so, it is possible that two-thirds of the energy needed for home heating could be obtained from the sun and from wind-electric generators, and it would be no more expensive than coal over a period of years.

Is atomic energy now available? In order to obtain atomic energy, uranium 235 must be separated from the uranium 238 with which it is mixed. A pound of uranium 235 will give off as much energy as about 1500 tons of coal or 200,000 gallons of gasoline.

Controlling the release of the energy of uranium is difficult. Unless a large amount of the material is used in one place, it soon stops giving off energy at usable rates. The uranium engine must be protected to prevent dangerous radiation and poisoning. Nobody knows the real cost of uranium 235 or of the energy that it can produce. Production of uranium has thus far been paid for by tax money.

Uranium can be used to heat water, to generate steam, or to heat air. The heat then can be used in common steam engines or for heating space in buildings. It is doubtful that a safe uranium

engine small enough to pull trains or run automobiles is possible.

Does cost determine what energy is available? The best single reason for using soft coal is its low cost. In order for uranium to be as cheap as coal at $15 per ton, its cost would have to be about $2300.00 per pound. This cost may eventually be possible. Coal is often cheaper than water power for generating electricity. Only about one-fifth of the cost of electricity pays for fuel when coal is used, the rest of the cost being for wires, machines, and services. Cost will determine what energy we use.

DEMONSTRATION: WHAT MATERIALS ARE IN COAL?

What to use: Test tube, stopper, L-shaped delivery tube with end drawn to jet, coal, ring stand, clamp, burner, litmus paper.

What to do: Put some coal into the test tube, holding the tube almost level with the clamp. Put the stopper into the tube, with the jet tube pointing upward. Heat the coal for some time. Test the escaping gas with wet litmus paper. Light the gas which comes from the jet tube.

When action stops, break the test tube. Examine the solids remaining. Smell and examine the tarry materials in the tube. Hold a piece of coke in the flame to see how rapidly it burns.

What was observed: Describe the appearance of the materials driven from the coal by heat. What is left behind?

What was learned: What materials in coal can you identify?

Exercise

Complete these sentences:

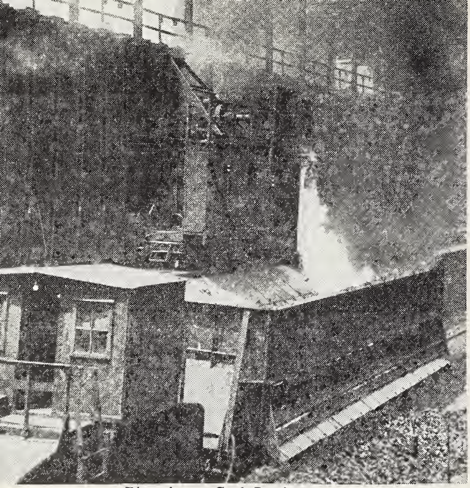
Much of the energy used by railroads comes from —1—. More than half the electricity generated obtains its energy from —2—. Useful energy divided by total energy is —3—. The best steam engines are about —4— per cent efficient. Most homes are heated by —5— using stoves or furnaces which waste —6— per cent of the fuel. About —7— of the dry-weather water power available is now used to generate electricity. A pound of uranium 235 will give off as much energy as —8— tons of coal. Uranium is likely to be used to produce energy in the form of —9—.

3. *What can we use for fuel?*

Although coal, oil, gas, and wood are the most common sources of energy, they may be used in a variety of forms for fuel. A fuel must burn easily, it must be convenient to handle or control, and it must be plentiful and cheap.

What are the common fuels? Among the best fuel woods are the hardwoods, oak and hickory; and the softwoods, pine, fir, and tamarack. The hardwoods burn with a steady slow heat and produce lasting coals. The softwoods contain more resin and make a hotter, quicker fire. Pitchy softwoods are excellent kindling fuels.

There are various grades of coal used for fuels. The common coal is bituminous, or soft coal.



Bituminous Coal Institute

Hot coke is pushed from the ovens, where it is made, into a car.

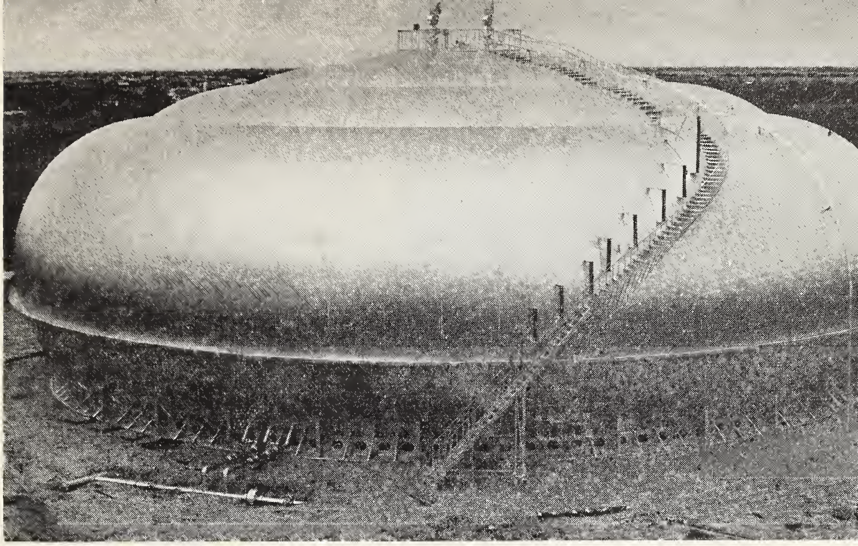
It is made of carbon and various hydrocarbons, materials which are chemical compounds of hydrogen and carbon. Anthracite, or hard coal, is more nearly pure carbon than is soft coal. Because of this fact, hard coal burns with a slower, cleaner flame than does soft coal. In some regions peat, which is a partially formed coal, is burned as a fuel. Lignite coal is between peat and soft coal in its structure, being brownish black and somewhat woody.

Coal is the raw material from which we manufacture two most important fuels: coal gas and coke. Both are produced by the same process. The soft coal is heated in a furnace with an insufficient supply of air, so that burning is incomplete. The gas formed is carbon monoxide [CO]. This gas, which is poisonous, is burned in the gas stove. There are various compounds of hydrogen and carbon added to manufactured gas to make it hotter. Another gas with a bad odor is added to make us aware of the coal gas when it escapes.

The coal gas is run through various towers and scrubbers where water is used to absorb and dissolve the sulphur, ammonia, and tars which come from the coal. Fuel gas is stored in tanks until used. The solid material left behind is coke, which consists of the ash and carbon.

Natural gas is burned as a fuel —sometimes with little treatment, sometimes after the more explosive gases have been removed. Natural gas is generally cheaper than manufactured gas. It is composed of a mixture of compounds of hydrogen and carbon.

Crude oil is the source of the fuel oils, gasoline, and kerosene. The materials in crude oil boil at different temperatures. The first liquids which boil off in the refinery are the most explosive gases.The liquids are further distilled by heating them and collecting the vapors as they pass off. Each increase in temperature drives off a different type of hydrocarbon fuel. Kerosene, gasoline, naphtha, and benzine are some of the products which have fairly low boiling points. The heavier oils and fuel oil boil at higher temperatures. Finally there are left only the waxy paraffins and tars, which are next separated. The whole process of manufacturing fuels from crude oil is called refining.



Chicago Bridge and Iron Company

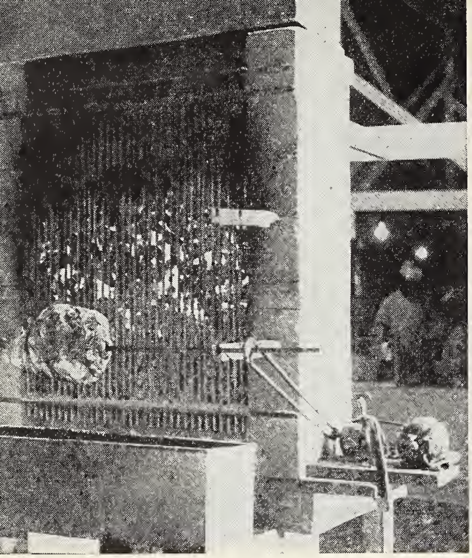
Gas molecules contain so much energy that gases must be confined in closed containers. This container is used for storage for natural gas.

What are the products of burning? Although we burn fuels to obtain either heat or light, the chemical change called burning produces several new materials from the fuel and oxygen. When carbon burns, carbon dioxide is produced. Because all common fuels contain carbon, their flames contain carbon dioxide. When hydrogen burns, water is formed. Not all fuels contain hydrogen in any large amounts. Charcoal and coke contain almost none. Water, then, may or may not be a product of burning.

When wood burns, water is released, and carbon dioxide forms. The water is chemically part of the wood.

There are several products of partial burning. One of these is smoke. Smoke consists of any solid or liquid fuel material which cools before the process of burning is complete. Smoke contains carbon, tars, and oil. Another product of incomplete burning is carbon monoxide, which forms in gasoline engines used on the farm pump and washing machine, in the automobile, and in stoves which have insufficient draft. Since this gas is colorless, odorless, tasteless, explosive, and a deadly poison, one cannot be too careful to guard against its dangers. Broken exhaust pipes, closed garages, and closed rooms are particular sources of danger.

A by-product of burning which is released from the fuel is ash. Wood ash contains the minerals taken from the soil by the plants. Coal also contains particles of soil and rock as impurities. These materials often melt together to



Radiant heat from the glowing charcoal cooks the ham as it is slowly turned by the motor. Why is it unnecessary for the ham to be above the fire?

form clinkers in the furnace.

How do we determine value of fuels? The value of a fuel depends in part upon the heat it will produce.

To measure the amount of heat given off by burning materials, a calorimeter [kăl′ō·rĭm′ē·tẽr] (p. 87) is used. It consists of an inner vessel in which the fuel may be burned in a supply of oxygen. The fuel is set on fire by use of a wire heated by electricity. The heat is taken up by water in a second container which surrounds the first. The weight of the water and the change in temperature are measured. The two multiplied together give the number of heat units given off by the fuel. Allowance is made by reference to tables for the heat taken in by the metal containers.

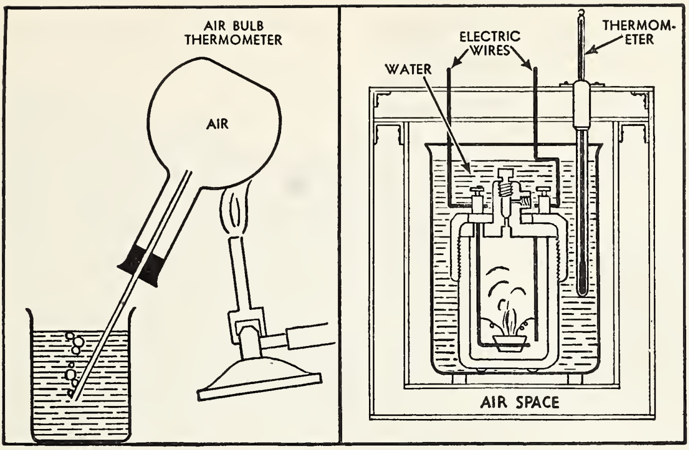
Use of this device for measuring the true value of fuels saves thousands of dollars yearly. Fuel value of foods is also determined by burning dried samples in the calorimeter.

There are two different units of measuring heat. One, the British thermal unit, abbreviated B.t.u., is the amount of heat required to raise one pound of water one degree Fahrenheit. The other unit, the calorie, is the amount of heat required to raise one gram of water one degree centigrade.

The approximate amount of heat in fuels is shown in the following list.

FUELS	B.T.U. PER POUND
Oak wood	8,000
Peat	7,000 to 9,000
Charcoal	12,800
Soft coal	11,700 to 14,000
Hard coal	12,500 to 14,500
Fuel oil	18,000

The actual value of fuel is determined, not only by the number of heat units per pound, but by the cost of the fuel and by the amount of heat that can be obtained from the fuel by burning it in a furnace. Oil can be burned somewhat more completely than can most coal, but it also costs more. Hard coal costs more than soft coal. In most parts of the United States, and under most conditions, soft coal supplies the most energy per dollar. In some



The effect of temperature changes in causing expansion and contraction of matter provides an indirect way of measuring temperature. Heat is measured by burning fuel or by placing a hot object in the container surrounded by water.

sections, where freight rates are high and other fuels are plentiful, coal may be too expensive for use in house heating. In these localities the cheapest source of heat may be gas, oil, wood, or electricity generated by water power.

DEMONSTRATION: HOW IS HEAT ENERGY MEASURED?

What to use: Beakers, piece of iron, ring stand and burner, balance and weights.

What to do: Heat a piece of iron by putting it into boiling water in a beaker. Have ready a beaker containing 300 grams of cold water, with the temperature noted. Put the iron into the cold water, stir the water, and quickly note the increase in temperature.

What was observed: Calculate the number of calories carried by the piece of iron, by multiplying the weight of the water by the increase in temperature in centigrade degrees. Your results will be inaccurate. Why?

What was learned: How is the amount of heat in an object measured?

Exercise

Complete these sentences:

Soft coal is called —1— coal. It is used to make two other fuels, —2— and —3—, by heating it with a small supply of air. When crude oil is distilled the liquids with the lowest —4— pass off first. All fuels contain —5— and most of them also contain compounds of —6—. We burn fuel to obtain —7—. The poisonous gas formed by partial burning is —8—. The amount of heat required to raise one pound of water one degree Fahrenheit is one —9—.

Arkansas Chamber of Commerce

Bauxite, the ore of aluminum, is mined by a power shovel. This process is called strip mining.

4. How do we obtain materials from the earth?

It is relatively easy to obtain limestone, sand, and clay from the earth, for they are so plentiful that it is only necessary to loosen them and take them away. Since other materials are scarcer, it generally is necessary to use more complex methods to obtain them for use. There are three general methods of obtaining these needed materials. Strip mining consists of removing the layer of surface soil and then digging the ore with power shovels. Shaft mining consists of making holes in the earth which extend to the ore. Use of wells provides means of obtaining materials which are in liquid or gas form.

When is strip mining used? Three materials often exist in large enough quantities to be obtained by strip mining. These are coal, iron ore, and copper ore. In a few places other ores may be obtained by strip mining. The usual method, after the earth is stripped away, is to dig away with a power shovel a large area of ore, leaving a hole in the ground equal to the depth that can be reached with the shovel. The shovel is then lowered and the process is repeated. The sides of the open pit formed are left in terraces on which railroads or truck roads are built to provide means of removing the ore. In a few modern mines the ore is

elevated to the top of the pit on conveyor belts—long rubber belts which are turned by engines and which carry the ore on their top surfaces.

Open pit mines can be seen in many places. Among the largest are the coal mines in Illinois, the iron mines in Minnesota, and a copper mine in Utah. These mines are so large that they are man-made valleys.

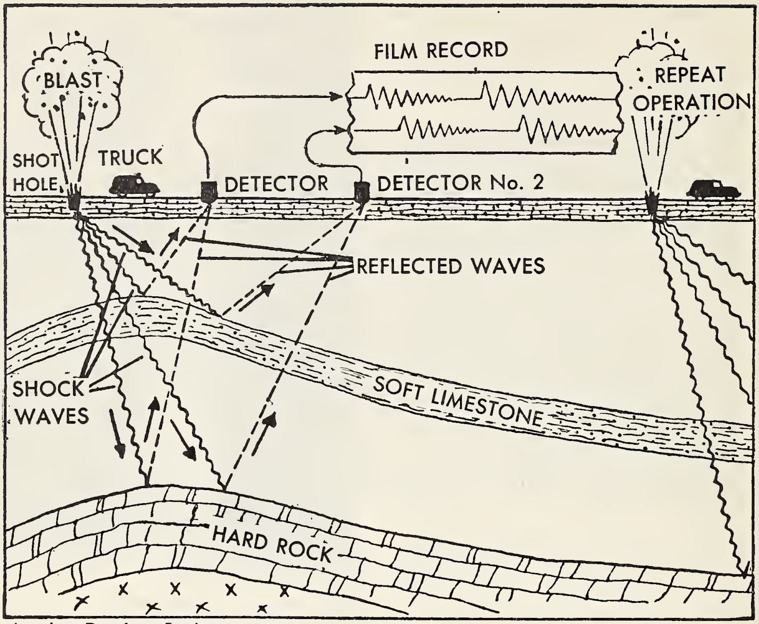
When are shaft mines used? Many valuable mineral products are not located at the surface of the earth. It is not generally easy to find these scarce materials. Minerals are located in various ways. Geologists obtain information about the general nature of rocks by observing surface rocks, by a study of the history of the region, and by studying the materials brought to the surface either from deep wells or by erosion. Where there is evidence that an ore may be found, test shafts are dug, or wells or test holes are drilled into the ground to obtain samples. More recently earth shock waves have been used to study underground formations. Recorders of waves are placed in various positions, and a small charge of dynamite is exploded. The shock waves travel differently in different formations and give an indication of what exists underground.

The mine itself usually consists of a shaft which extends downward and tunnels running more or less on the level from the shaft. Occasionally, ore formations may be followed into hillsides almost on the level. In the shaft there is some sort of elevator, not much different in operation from the ones you ride. Underground railroads or conveyor belts carry the ore to the shaft or to the opening. Sometimes buckets hung on steel cables are used to carry ore either inside the mine or from the opening to a railroad.

Sullivan Machinery Company

Drills driven by compressed air make holes in the rock and ore. Blasting powder or dynamite placed in the holes explodes and loosens the mineral.

In many mines, where the rock formation is not very strong, it is necessary to reinforce the roof and walls of the tunnels with heavy timbers. Since the tunnels must follow the veins of ore, they



American Petroleum Institute

Because varying rock formations reflect shock waves differently, it is possible to use a seismograph to locate underground formations in which oil and other minerals might be found.

sometimes are quite crooked.

The ore or coal is generally loosened by blasting. A series of holes is drilled into the end of the tunnel, called the face, and the holes are filled with an explosive. When it explodes rock is loosened. The loose material may be loaded onto cars either by men shoveling or by mechanical loaders. The work of mining often is difficult and dangerous.

How are wells used to obtain materials? While salt may be mined as are other minerals, the fact that it is easily dissolved makes it possible to obtain it from wells. When an underground deposit is discovered, a large well is drilled deep enough to reach it. The well is provided with two pipes, one inside the other. Water is pumped underground through one pipe. When it dissolves as much salt as it will hold, it is pumped to the surface. The water is evaporated to obtain the salt. Since most rock materials do not dissolve readily in water, this method produces fairly pure salt.

Sulfur is obtained in a similar way, except instead of using water to dissolve the sulfur, it is melted by use of hot water. In order to make the water hot

enough—more than 300 degrees F.—it is heated far above its normal boiling point under pressure. The melted sulfur and water are pumped to the surface. The sulfur becomes solid when it cools.

Oil and gas also are obtained from wells. In most cases it is not necessary to pump these materials from the ground. Gas tends to rise because of its natural tendency to expand when pressure is released. Oil may be forced to the surface either by expansion of gas or by pressure of underground water. Oil is pumped from wells to obtain what is left after there is no longer pressure.

In early days of oil production too many wells were drilled too close together, and the pressure produced by water or gas soon was reduced so much that oil would no longer rise. Today wells are drilled farther apart, and the flow of oil is regulated so that it maintains a constant pressure for as long as possible.

Pressure on oil may come from gas dissolved in the oil. If you put a one-hole stopper with a glass tube in it extending to the bottom of a bottle of pop, you have a similar kind of pressure. Pop shoots from the tube as long as the liquid contains dissolved gas and as long as enough remains to give off gas. Sometimes natural gas lies above the oil and exerts pressure on it. In either case pressure on the oil may be maintained by pumping the gas back into the well instead of allowing it to escape. Water is also pumped into some oil wells to force the oil from the spaces in the porous sands.

Exercise

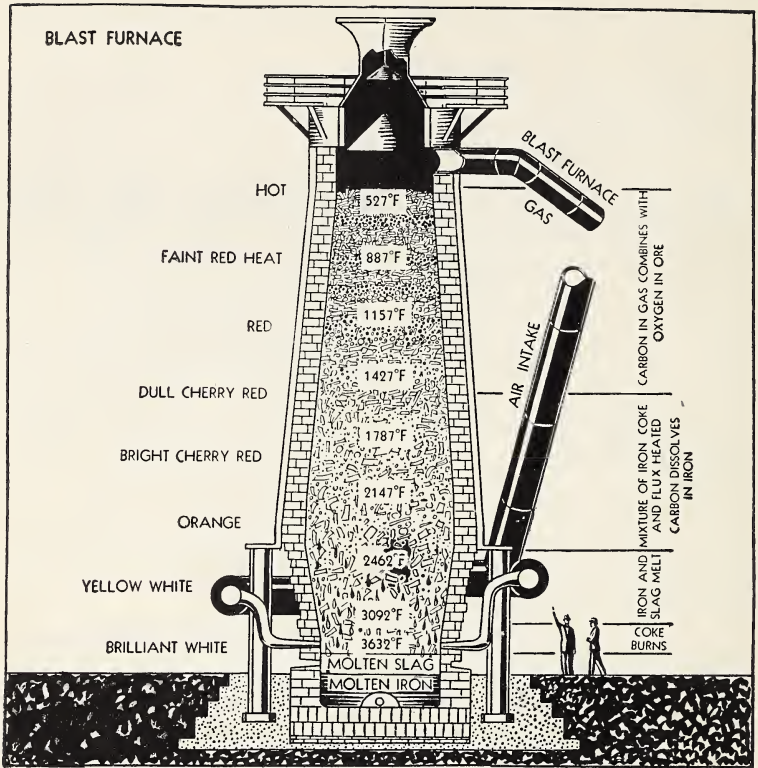
Make a table by ruling your paper into three columns. Head the columns as follows: STRIP MINING, SHAFT MINING, WELLS. In the correct columns place the names of natural materials obtained by each of these three methods.

5. How are metals produced?

When we have obtained the metallic ores from the earth, we still have a material far removed from its usable form. It is difficult to visualize a lump of brown rock as containing the polished steel of a razor blade, or a shining blue stone as part of an electric motor.

There are three general ways of obtaining metals from their ores: by use of electricity, by use of carbon to remove the oxygen, and by use of heat or roasting. Some metals may be purified by one of these methods; others must be purified by all three.

How is the blast furnace used? Metals in ores are separated from oxygen in the blast furnace. To purify iron ore, the ore, together with coke and limestone, is put into the furnace, which is a chimney perhaps 90 feet high. The coke burns to supply heat, and also reacts chemically with the ore, combining with the oxygen



General Motors Corporation

This diagram shows the changes which take place in a blast furnace.

and leaving the iron free. Carbon dioxide and carbon monoxide are formed. To increase the temperature of the reaction, blasts of hot air are blown into the furnace through openings near the bottom. The chemical equation for purifying a typical iron ore is as follows:

Fe_2O_3	+	2C	→
Iron oxide		**Carbon**	

2Fe	+	CO	+	CO_2
		Carbon		**Carbon**
Iron		**monoxide**		**dioxide**

The limestone does not take part in this change.

The melted metal runs to the bottom of the furnace where it is drawn out through a hole. The limestone melts and reacts with impurities in the ore. The limestone and impurities form slag which floats on the iron. This slag is drawn out through another hole. The blast furnace is kept in operation for months without stopping.

The iron is run into molds made of sand, and it cools in the

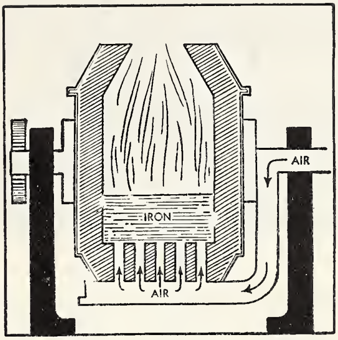
form of pigs. Pig iron is more than 90 per cent pure iron.

What is roasting? Platinum, mercury, silver, and gold may be separated from their ores by heat alone. Ores of other metals which contain sulfur are commonly heated to a high temperature to drive off the sulfur. The remaining ore is then purified by removing the oxygen by use of coke in a blast furnace. Some ores containing carbon dioxide in chemical combination with the metal are also purified by heating to drive off the gas. The resulting ore is an oxide which may be reduced in the blast furnace. Zinc, copper, and lead ores are treated by roasting before being reduced in a furnace.

When is electricity used? Several metals including potassium, sodium, calcium, magnesium, and aluminum are purified only by the use of an electric current.

Under certain conditions electricity may be used in the purification of any metal. Copper is generally purified by use of electricity as the final step of preparing it from its ore.

What does the converter do? When it is formed into pig iron, iron contains considerable carbon. To remove the carbon, the iron either is poured from the blast furnace directly into a converter, or the pigs are remelted, usually by heating with coke or with an electric current. Blasts of hot air are blown through or over the melted iron in the converter. The air burns out the carbon and sulfur, and the impurities pass



Air blown through the melted iron in the converter burns out many impurities.

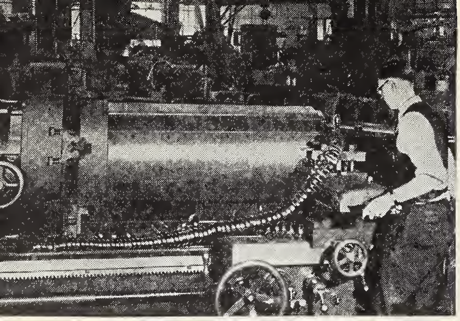
into the air in a spectacular flame. The operation must be controlled rather exactly and stopped at the right time, or the iron too will combine with oxygen and change back to ore.

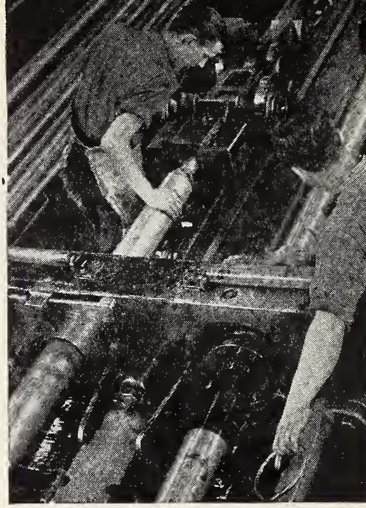
There are a number of different types of converters in use. The original converter was developed by Bessemer. This furnace is used today for making much of the steel used in industry.

The difference between steel and iron is based upon such technical points that there is no one way of distinguishing the two metals. Steel is formed by treatment of iron—either by adding or removing carbon, by putting into the iron other metals, or by special methods of treating the iron with heat.

How are metals worked? The properties of metals make them indispensable in manufacturing, building, transportation, and other industries. Metals are worked in several ways.

Melted metals may be poured





(Left) American Tool Works Company. (Right) Aluminum Company of America

(*Left*) In this picture, a cylinder of metal is rotated by a lathe. A tool cuts from it a long spiral shaving. (*Right*) This shows a step in the process of drawing aluminum into tubing.

into molds shaped to form the desired articles. Parts of engines, stoves, large machines and some tools are made by this process, which is called casting. Cast iron is brittle and rather easily broken. Cast steel may be quite strong.

Iron which can be hammered —the type used in making horseshoes—is called wrought iron. Wrought iron and steel may be heated until it is soft, and stamped or pressed by machines into various shapes. Parts of automobiles and many tools are made by this process, which is called forging.

Metal may be rolled or drawn into thin sheets or tubes. So-called "tin" cans, kettles, metal houses, culverts, tank cars, and stovepipes are common articles made from sheet steel. The sheet steel is made by forcing a huge bar of iron between rollers. Each set of rollers presses the sheet thinner than it was before, until it reaches the desired thickness. Metal may be rolled either hot or cold. Metal may also be drawn through holes to form wires and pipes.

Although it is tough and hard, metal may be cut, ground, or polished. The metal lathe turns a piece of metal so that when a sharp tool is held against the turning metal a shaving is cut from it. Almost perfect roundness may be obtained by using the lathe. Drills are used to bore holes in metal. The insides of automobile cylinders are ground with an abrasive (grinding powder or stone). Most metals may be cut with a hack saw.

Metal may also be cut with an oxyacetylene [ŏk′sĭ·*ȧ*·sĕt′*ĭ*·lēn, fuel gas] torch. This torch produces a flame hot enough to melt and burn through an inch-thick steel bar in a few seconds. Metals can be joined together by melting. Sometimes heating and hammering are sufficient to join pieces of metal. Blacksmiths may weld a new point on a plowshare,

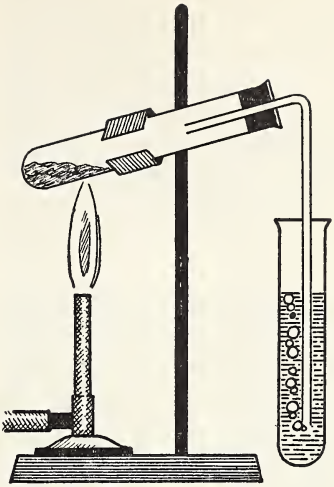
or they may weld a broken automobile bumper. Welding is joining pieces of metal by melting them together.

Of what use are alloys? There are many needs for which there is no natural metal that exactly serves. To meet these needs, various mixtures of metals called alloys have been developed.

One of the oldest and commonest of the alloys is solder [sŏd′ẽr]. Before more modern methods were developed, solder was used extensively to join together metals with high melting points. Solder is a mixture of lead and tin in various proportions, and melts at temperatures of around 350 to 400 degrees Fahrenheit. To solder two pieces of metal, the surfaces to be joined are cleaned with acid or by polishing. Then a hot soldering iron or copper is pressed against the metal surfaces to heat them, the hot iron touched with the solder, and the drop which forms is used to join the pieces of metal. Pots and pans and water pipes must never be soldered. Use of solder in contact with foods is dangerous, for lead is poison.

Steel alloys are used widely. When combined with the rare metals—tungsten, chromium, vanadium, cobalt, manganese, or molybdenum—steel becomes harder and tougher. Cutting tools, magnets, armor plate, ball bearings, and strong machines are made of these steel alloys.

The wire used in electric heating coils is nichrome, which is an alloy of iron, chromium, and nickel. This wire resists burning and has a high resistance to electricity. The five-cent coin is an alloy of copper and nickel or silver. The white color is caused by the small amount of nickel. Alloys are used to harden gold and silver. Nickel in gold makes it white. Aluminum is almost always strengthened or hardened by alloying it with other metals. Older alloys are bronze, brass, and pewter. Pewter, being a lead alloy, is dangerous to use for containers of foods.



This diagram shows how you should arrange the apparatus for the next demonstration.

An interesting alloy is used in the automatic fire sprinklers used inside stores, factories, and other buildings. A plug is held in an opening of a pipe by a piece of metal which melts readily. When the building begins to burn, the heat melts the metal, and the plug is forced from the

pipe. The flow of water is then started from the sprinkler.

DEMONSTRATION:
HOW ARE ORES PURIFIED?

What to use: Copper oxide or lead oxide, charcoal, hard glass test tube, ring stand and clamp, burner, stopper, delivery tube, test tube, limewater, mercuric oxide, splint. (See page 95.)

What to do: Set up the apparatus as shown in the diagram. Heat the mixture of copper oxide and charcoal for several minutes in a hot flame. Test the gas as shown. When the tube cools, pour the contents into a large test tube of water, and shake vigorously. Pour off the liquid and floating solids. Examine the sediment.

Heat mercuric oxide in the hard glass test tube. Test the gas given off with a glowing splint.

What was observed: Describe all changes which occurred in each experiment.

What was learned: What are two ways of separating metals from their ores?

Exercise

Complete these sentences:

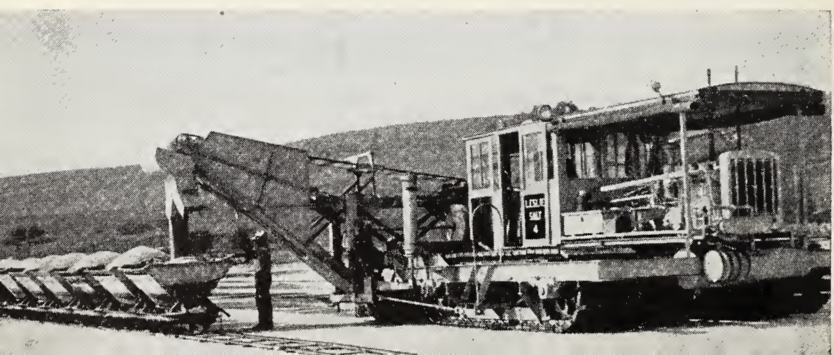
Into the blast furnace are put —1— and —2— which react chemically to produce —3— and —4—. —5— is put into the blast furnace to form slag. Many ores are —6— to separate the metal from sulphur or carbon dioxide. Steel is made from the element —7—. Metals may be worked because they soften when —8—, and can be drawn into —9— or rolled into —10—. A mixture of metals is an —11—.

6. What are some common chemicals?

When you see all the things offered for sale in a modern store, you may wonder how so many different materials can be produced. Cleansers, paints, cooking chemicals, plastic articles, linoleums, and oils are found in seemingly endless numbers. At the service station are more chemicals and materials. How are they all made?

What are some household chemicals? Some common household chemicals are fairly simple materials. Others are more complex. Two cleaning

Common salt is prepared by evaporating sea water. The salt is being loaded into hopper cars.



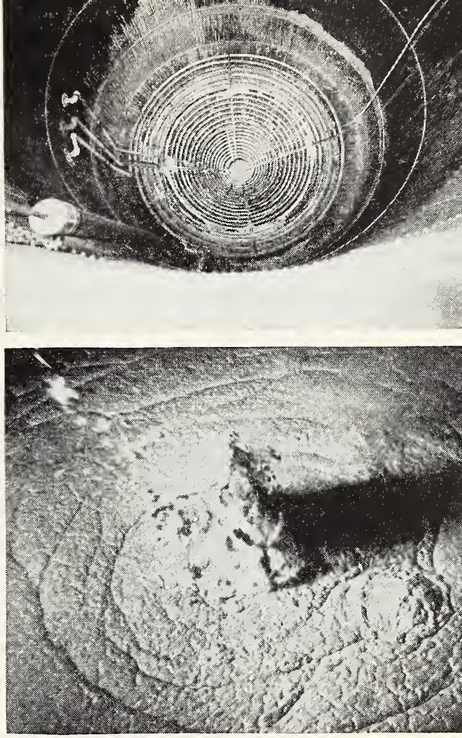
materials, lye and ammonia, are bases. That is, they turn litmus blue, are bitter, and react with acids. Both are used for removing grease, which is a complex acid type of material. Soap is a product resulting from the chemical combination of lye and fat. Chemically soap is a salt.

A salt is any chemical formed by action of a metal or base with an acid or acid-forming element. Table salt, soda, and water softeners are salts. Baking powder is composed of an acid salt and an alkaline salt sometimes mixed with a starch. The acid salt may be cream of tartar, and the alkaline salt is soda. When the two react they form a third, harmless salt which remains in the food, and release bubbles of carbon dioxide. The starch serves to keep the salts from reacting in the can. Alum, another acid salt, has been used in some baking powders.

Few acids are used in the kitchen. Vinegar is dilute acetic acid and is the only common one. Of course all sour foods contain acids.

Scouring powders are generally a very finely ground rock material originally made by sea plants and animals. Most scouring powders also contain a little water softener and soap. The new suds formers, called detergents, which are used instead of soap are quite complex compounds.

Polishes and waxes quite often are simpler than they are advertised to be. Most of them belong to the group of oils and waxes, and chemically they are hydrocarbons. Paraffin or a wax made from sugar cane or other plants may be dissolved in some solvent such as kerosene or light mineral oil to make a furniture polish.



Procter and Gamble

The soap kettle, heated by coils of steam-filled pipe, is three stories high. You see the top view above. The boiling soap below erupts like a small volcano.

What are some important industrial chemicals? The list of industrial chemicals is almost endless, but a few are used to produce a great many others. One of these fundamental chemicals is sulfuric acid. Without even knowing it, the average person

in the United States uses about 100 pounds of sulfuric acid each year. This acid is made by burning sulfur in air to produce sulfur dioxide, and then adding, by a complex chemical method, another atom of oxygen to each molecule of sulfur dioxide to form sulfur trioxide. This gas then reacts with water to form sulfuric acid, H_2SO_4. About one-fourth of the sulfuric acid produced goes to the fertilizer industry. Another fourth goes to the steel industry, where it is used to take the rust scale off newly rolled sheet iron and for other purposes. Numerous chemicals are manufactured with the help of sulfuric acid. If it is boiled with table salt, hydrochloric acid is formed. Sulfuric acid is used also in making paints and pigments, rayon, automobile batteries, and many other common things.

Sulfuric acid is not a safe material to handle. It causes serious burns. In mixing it with water, it is poured very slowly, with careful stirring, into cold water. If water is poured into sulfuric acid, it may become so hot that it will boil and spatter acid around!

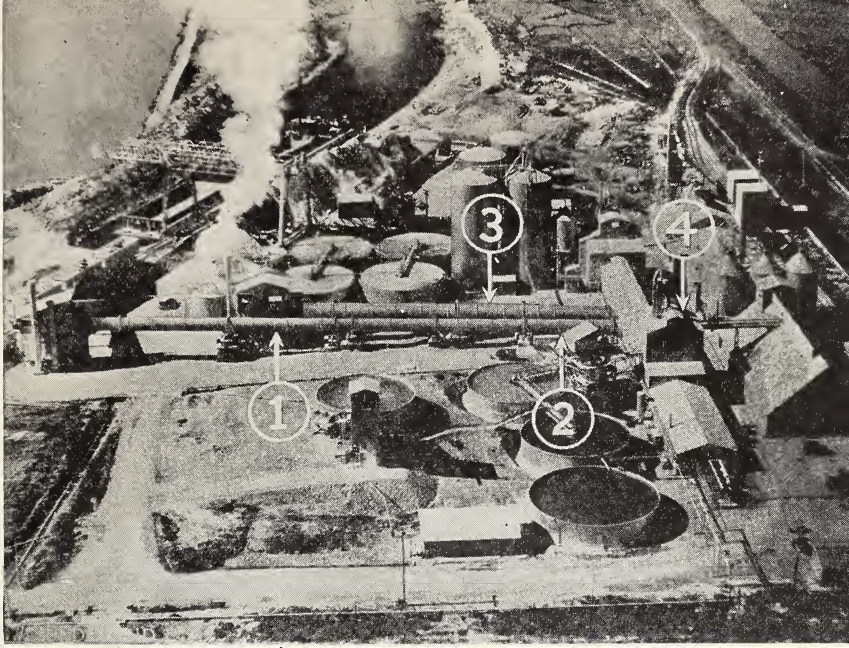
Another basic source of chemicals used in industry is coal tar. Coal tar is a complex mixture of chemicals. The tar is left after coke, fuel gas, and ammonia are separated from the coal. More than 200 different substances can be obtained from coal tar just by distilling it—that is, by heating it to different temperatures and collecting the vapors formed. Some of these materials are seen in moth balls; carbolic acid, a disinfectant; benzene, a solvent; and creosote, a wood preservative.

From the materials obtained from coal tar the industrial chemist can produce a great variety of materials. About 60,000 tons of dyes, including about a thousand colors, are made from coal tar every year. Many common drugs, including sulfanilamide and aspirin, are made from coal-tar chemicals.

Although coal tar does not smell like roses, violets, nor lilies of the valley, perfumes of flower odors are made from coal tar. Other chemicals made from coal tar are insect sprays, weed killers, rat poisons, and explosives. Even synthetic rubber is made from coal-tar chemicals.

Other basic chemicals of industry are made from limestone, salt, crude oil, and sea water.

What are some sticky molecules? Perhaps you have heard about a plastic with a memory. If it is shaped when formed in one shape, then changed to a second shape, and heated, it will go back to its first shape. These changes have nothing to do with memory. The molecules of plastics, and of many other materials, stick together in long, tangled chains. This causes the material to be able to stick together even under pressure. The molecules of the so-called "plastic with a memory" are stretched when formed into a second shape, and they go back to the first shape when released by heat from pressure.



Westvaco Chlorine Products Corporation

This modern chemical plant produces lime and magnesia—both bases used in industry. Number 1 is the kiln in which lime is separated from limestone. Number 2 is the lime cooler. Number 3 is a magnesia kiln, and 4 is the cooler. The tanks are used for separation and storage.

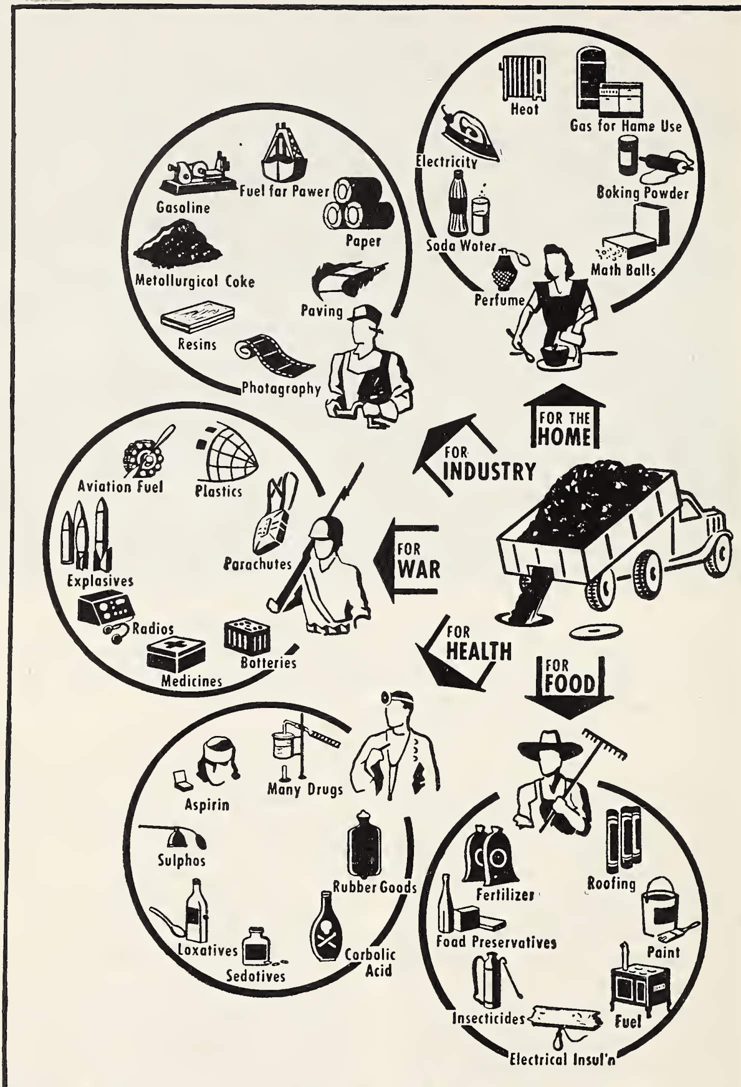
Many natural materials are made of these tangled molecules. Cotton, silk, rubber, leather, and photographic film are made up of molecular chains. Nylon and artificial rubber, as well as plastics, are synthetic materials made of such molecules.

Chemists have had to learn a great deal about the structure of molecules in order to make them to order. While molecules are made up of atoms, it is not enough to know what atoms make up the molecules of these complex compounds. It is also necessary to know how the atoms are arranged and connected within the molecule in order to make needed materials.

DEMONSTRATION: WHAT CHEMICALS MAKE UP BAKING POWDER?

What to use: Baking soda, cream of tartar or alum, gas generator bottle, spoon, litmus paper, limewater.

What to do: Dissolve a rounded teaspoonful of soda in water in the generator bottle. Dissolve two spoonfuls of cream of tartar or alum in hot water. Test each solution with red and blue litmus paper. Put the stopper in the generator bottle, and place the



Bituminous Coal Institute

Coal is an important source of chemicals, from which more than 200,000 products may be made.

end of the delivery tube in the limewater. Add the second solution, just fast enough to keep a steady flow of bubbles rising.

What was observed: Which salt was acid? Alkaline? What color did the limewater turn? Was much gas given off by the soda?

What was learned: State the test for an acid and for an alkali or base. What is the test for carbon dioxide? How does baking powder produce a gas?

Exercise

Complete these sentences:

A —1— turns litmus blue. An —2— turns litmus red. Some —3— also change the color of litmus. Baking powder releases the gas —4—. The acid former in sulfuric acid is —5—. Sulfuric acid is used to remove —6— from iron. Heating a material and sorting vapors by cooling at different temperatures is —7—. A disinfectant made from coal tar is —8—. Plastics have their —9— arranged in tangled chains. Production of new materials is controlled by —10—.

7. Can we use plants to supply needed materials?

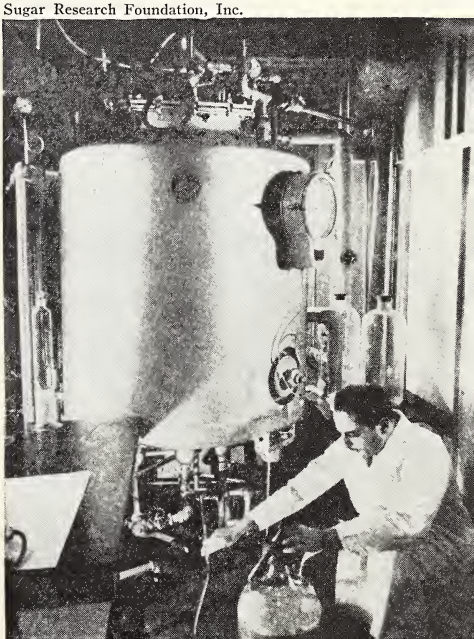
Although people can easily see that we are using our irreplaceable resources rapidly and often wastefully, they may think that there is no need to be concerned about the future. Many people believe that we will have atomic energy to replace coal as a fuel and can use plant products to produce organic chemical materials. This belief may be justified, but there is evidence that it is not. Most useful plants grow only on fairly good soil, and food plants need the best soil. We have been growing, for several years, about as many crops as the land will now support, and have had very little left over. Our poor management of soil has reduced rather than increased the amount of land available for crops.

Insofar as it is possible, we still should use plant products to provide industrial chemicals. Plants produce several kinds of materials which have industrial uses. Among these are sugar, oils, starch, proteins, and woody materials.

How is sugar used in making chemicals? Some of the chemi-

Sugar is used in the manufacture of many kinds of drugs and drug preparations.

Sugar Research Foundation, Inc.



cals made from sugar are direct products. Some are by-products. A by-product is something produced as part of a process, but not directly related to the main product.

Sugar is used chiefly in foods in its pure state. When sugar is fermented by yeast, it is changed to an alcohol called grain or ethyl alcohol. Alcohol is a chemical compound with the formula C_2H_6O. This alcohol may be used as a fuel, although it contains much less energy per gallon than does gasoline, and is more expensive. It is used as a solvent for shellac and other chemicals. Alcohol is used to make a soapless detergent, and it is one of the chemicals used in producing a synthetic rubber.

Bacteria also act upon sugars, producing a number of chemicals. The most familiar of these is vinegar, which develops from fermented fruit juice. Lactic acid, which is the sour-milk acid, may also be made from sugar. Other chemicals from sugar may be used in making plastics, solvents, airplane dope, rayon, and industrial chemicals.

By-products of sugar cane may be used for making waxes, insulation board, drugs, and plastic materials.

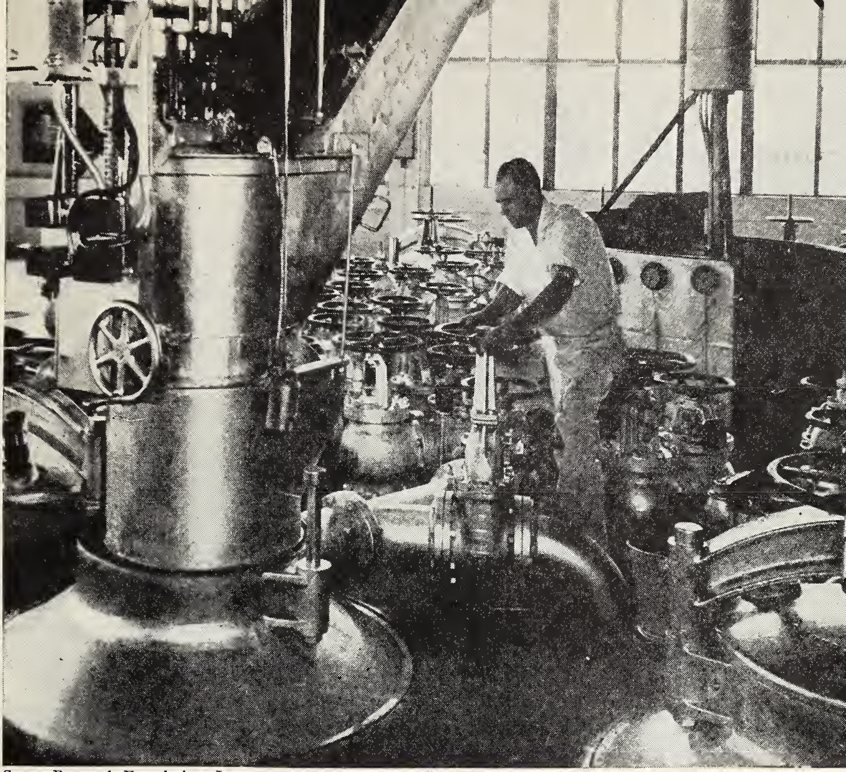
Sugar may be obtained directly from sugar cane and beets, or it may be made from starch. The chemical name of cane and beet sugar is sucrose. Another sugar, dextrose, is made from starch by treating it with acids. Sucrose is a complex or double sugar made when two molecules of simple sugars are combined. Dextrose is called a simple sugar.

Dextrose will serve for many of the uses that cane sugar has. Dextrose or glucose, often called grape sugar, is produced by green plants and is found in fruits and other plant parts.

What oils are obtained from plants? In many ways plant oils are essential for industry. Paints are commonly made in part of linseed oil, which is pressed from the seeds of the flax plant. Oil of turpentine is also used in paints. It is made by distilling the sap collected from pine or other trees, leaving behind the solid materials called resins. Although some very light mineral oil is used in paints, no real substitute for vegetable oils in paints has been discovered.

Almost any seed may be used as a source of oil. Commercially important oils are obtained from peanuts, soybeans, cottonseed, castor beans, and corn. These oils have many uses in the manufacture of linoleum, paints, soap, and plastic-like materials. The oils themselves have numerous uses for foods, medicines, and machine lubrication.

What plant proteins are useful? Proteins are complex chemicals produced by plants chiefly in their seeds. A few plants, particularly those of the legume family, contain some protein in their stems and leaves. Commercially one of the best sources of plant protein is the soybean. A kind of protein, gluten, is ob-



Sugar Research Foundation, Inc.

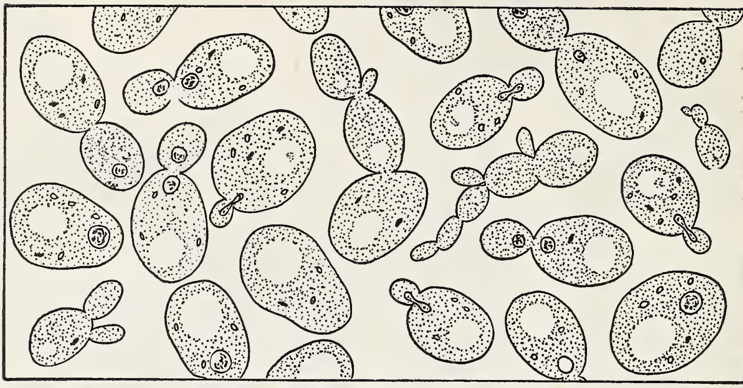
Sugar beets, finely sliced, are soaked in hot water in these tanks to remove the sugar.

tained from wheat. Proteins differ from other plant products in that they contain the element nitrogen in their molecules.

Plastic materials, including artificial wool, enamel finishes, and molded plastic articles, are made from plant proteins.

What woody materials have value? The largest portion of any plant is found in its stems and leaves. Almost all of the weight of the usable part of a tree is in the trunk and branches. The corn plant is mostly stalk, leaves, and cob. While the roots are made of useful materials, we cannot obtain them at reasonable cost.

One of the important wood materials is cellulose. It is somewhat similar chemically to the sugars and starch. That is, it is a chemical compound of carbon, hydrogen, and oxygen. Cellulose is used for making rayon, cellophane, and many kinds of tissue. There are other chemicals in wood, most of which have no great value at present. Experiments are being conducted to learn how to use these now-



Yeast cells, greatly magnified in this drawing, convert sugars into alcohols.

wasted wood materials for making plastics.

When wood is fermented by the action of certain yeasts, several kinds of alcohol are produced. One of these, wood alcohol, has important industrial uses as a solvent. This alcohol is very poisonous and causes blindness if it comes into contact with the eyes. Blindness may also occur if one accidentally drinks wood alcohol, because it produces permanent injury to the nerves of the eye. Experiments are being conducted to use wood waste for food for yeasts which can make proteins as they grow. The yeasts have been used experimentally for food, both human and animal, and contain almost as much nourishment as meat.

Wood materials contain materials which may be separated from the wood by distillation. One of these is wood tar. Wood tar is not quite so valuable as coal tar, but it can be used to make products similar to those obtained from coal tar.

Can plants replace other materials? Whether or not plants will ever replace coal and metal depends upon conditions we cannot foresee at present. It is possible that in the future we will be able to make use of materials now considered to be without value. We may be able to develop plants which will grow on land now considered to be too poor for useful crops. Some experiments indicate that we are making progress in this direction. In the southern states wasteland is being planted with quick-growing pine trees, and the trees are used like a crop as a source of wood pulp and chemicals. In some of the northern states poplar trees are similarly being grown as a quick-maturing crop. At present these trees are used chiefly for making paper, cellulose, and rayon.

If it becomes necessary we can perhaps use charcoal for smelting metals. Before this is done, however, it is likely that the last supplies of low-grade coal will be

exhausted, for wood generally cannot compete in cost with coal products.

Plastics may replace metals for a good many uses, but energy is required for their production. We may develop processes which will make it unnecessary to use materials now considered essential. For example, where we now use silver on photographic films, we may be able to substitute some undiscovered, replaceable chemical.

Swift and Company

The chemist finds new ways to market and use many products of the farm and forest.

DEMONSTRATION: HOW IS INDUSTRIAL ALCOHOL PRODUCED?

What to use: Yeast, molasses or corn sirup, flask, stopper and delivery tube, burner, stand, limewater, test tubes, iodine crystals, beaker, dish.

What to do: At the beginning of the period put one-fourth of a yeast cake and three tablespoonfuls of sirup into three-fourths of a glass of warm water in the flask, and stir them together well. Put the stopper and delivery tube in place, and put the end of the delivery tube into limewater in a test tube. Set the mixture aside in a warm place. As soon as bubbles rise in the limewater note any change in appearance. Keep the mixture warm till the next day.

The following day put a test tube into a beaker of cold water. Arrange the flask on the stand, and place the delivery tube in the cooled test tube. Heat the mixture in the flask gently, until a small amount of liquid collects in the tube. Do not let it boil violently.

Pour some of the liquid, which should be alcohol, from the test tube onto a flat dish, and light it. Note that it burns with a blue, almost colorless flame. Drop a few crystals of iodine into the remaining liquid. If they dissolve, you have tincture of iodine. (*Caution*: Sometimes poisonous materials are produced by fermentation. Do not taste the liquid.)

What was observed: What seems to occur when sugar ferments? Does alcohol burn? Is it a useful solvent for iodine?

What was learned: What evidence do you have that fermentation is a chemical change? How is alcohol produced?

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: SUGAR, OIL, PROTEINS, WOODY MATERIAL. In the correct column write the names of the following products made from these materials, using each word as often as necessary: alcohol, vinegar,

paint, artificial wool, rayon, plastics, enamels, wax, soap, cellophane, nitrogen compounds, lubricants, tars.

8. *Is the soil a storehouse for minerals?*

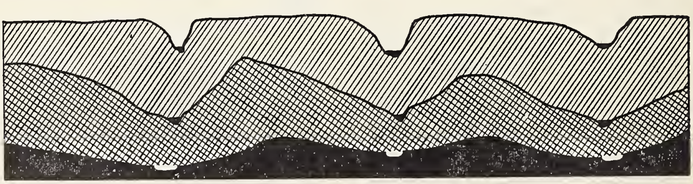
Ordinarily we do not think of growing plants as being related to mining. Yet in a way it is, for we use plants to remove needed minerals from the soil. Plants do not depend entirely upon soil minerals for their food-making, for sugars, starches, and fats are composed entirely of materials taken from carbon dioxide and water. Yet no plant can carry on its growth processes without minerals, and protein foods cannot be made without a sufficient supply of nitrogen salts.

How is soil formed? Soil is a complex mixture of materials. The mineral materials such as sand, clay, and gravel come from rocks. Humus, the black or brown material in soil, comes from partially decayed plants. The soluble minerals come from the action of bacteria on nitrogen of the air, and from the rocks and plants which leave their parts in the soil.

The process of forming soil is very slow. The breaking down of rocks into finer materials is called weathering. Weathering is produced by a number of natural forces. Chemical weathering actually changes the composition of the rocks. Oxygen combines with iron in rocks, forming rust. Carbon dioxide in water forms a weak acid, carbonic acid, and reacts with alkaline rock materials. The action of carbonic acid is still more important in speeding the dissolving of rocks. Limestone in particular is fairly soluble in carbonic acid.

Rocks are weathered mechanically by expansion and contraction as the temperature changes. The outer layers or particles of rock crumble as they are loosened by these forces. Freezing water is a powerful weathering agent. Ice takes up about 10 per cent more space than does water. As the water freezes in cracks or pores of rocks, the rocks are broken.

Plants themselves form soil in several ways. They weather rocks by breaking them with their roots. Lichens, which are simple, scalelike plants grown on rocks,



Running streams cut valleys into plateaus. Then the sides are washed down, and the valleys become wider. Finally the hills disappear, and the country becomes gently rolling.

U. S. Forest Service

A series of dams in a stream not only protects against soil erosion, but it also provides pools for fish and wildfowl.

crumble the surface of the rocks by the action of the chemicals they produce. When plants die they add humus to the soil. When the roots decay they leave some organic matter in the soil, and make it more porous. The leaves and stems of plants, if left undisturbed, fall to the ground and become part of the soil.

When there is some plant material in the soil, bacteria, earthworms, and insects live in it. They also help to weather rock.

What is good soil? A good soil is a loam, which is a mixture of rock materials and humus. Soil particles formed from rock vary in size and chemical composition. Gravel is coarse, and may be formed from any rock. Sand is finer, and usually is formed from quartz. Silt is still finer, and may be formed from various rocks. Clay is the finest of all soil, and is formed from shale or a mineral called feldspar, which is found in granite and other rocks.

A loam may be composed of different portions of these rock materials mixed with humus. If it contains a large amount of sand, it will dry rapidly. If it contains a large amount of clay, it will be sticky when wet and will dry in hard lumps. It will not drain well. A soil that contains a large amount of humus will be light in weight, will hold considerable water without being wet, and will crumble readily.

Soils must contain certain soluble minerals to be of value. Most rock materials contain enough impurities to supply a large variety of minerals in small amounts in natural soils.

How is soil kept fertile? Four


Swift and Company

Beef cattle given a free choice eat from the haystack grown on ground rich in calcium and phosphorus, leaving untouched the hay grown on ground lacking in these elements.

elements must be added to cultivated soils to replace what is removed. If you have ever seen the skeleton of a steer, you know that the bones are large and heavy. The minerals of this skeleton, which are chiefly calcium phosphate, came from the soil. The protein of the flesh was formed in part from the nitrogen of the soil. The elements potassium, phosphorus, nitrogen, and calcium are most rapidly removed from the soil by cultivated plants. If the soil is formed from limestone rock there will be enough calcium, but otherwise limestone must also be added to the soil to replace the calcium used by plants.

Phosphorus fertilizer is provided by phosphate rock which is found in large amounts in several states. The rock is treated with sulfuric acid, which causes the formation of a chemical called calcium superphosphate. This chemical is fairly soluble. Nitrogen fertilizer is made from two types of chemicals, ammonia compounds and nitrate salts. Ammonia gas obtained from manufacturing coke is combined with sulfuric acid to form ammonium sulfate. Nitrates may be made directly from nitrogen and oxygen of the air. Electric sparks cause the nitrogen and oxygen to combine in a form which make an acid when added to water. Some natural nitrate rocks are used for fertilizer. Potassium is obtained from potash rocks. Commercial fertilizer is expensive, but it provides the only means of improving much of the soil now in use within a reasonable amount of time.

Humus is added to soil by keeping and plowing in the straw of grain crops, by plowing into the soil crops grown for that purpose, or by spreading such materials as peat, peanut shells, or other plant material directly on the soil. Animal manures are also added to the soil to provide both nitrogen and humus. An abun-

dant supply of organic matter in soil increases somewhat the rate at which chemicals in the rocks are made available. Most rocks will not dissolve in any important amounts, but the action of bacteria makes them slightly more soluble.

Are we making best use of soil? If you drive around the United States you soon begin to realize the vast amount of land which is practically wasted. Large areas are covered with worthless bushes or weeds. Pastures often are almost bare of grass, and are full of weeds. Few forests of large trees are found in many states. Often farm crops are small and scanty, barely growing on soil that is poor in quality. Fortunately we also often see excellent crops, pastures green with tall grass, and flourishing woods.

Any soil that is not entirely rock will produce something of value. The kind of soil determines whether it will be corn or pine trees, or something else. The only way we can obtain minerals from the soil is by using the plants adapted to grow in that particular kind of soil.

Safeway Stores, Inc.

This home-made, portable burner makes possible burning of waste branches without injury to the soil or trees. The ashes may be dropped where needed to improve soil fertility.

DEMONSTRATION: DOES SOIL CONTAIN SOLUBLE MINERALS?

What to use: Soil samples, beakers, funnel, filter paper, burner, stands, watch glasses or flat glass saucers, test tubes, rain or distilled water.

What to do: Put three heaping tablespoonfuls of the soil sample into about 100 milliliters of rain or distilled water in the beaker, and bring it to the boiling point. Repeat, using tap water.

Put the funnel on a stand, with a test tube beneath. Put the filter paper in the funnel. Pour water from the soil sample into the funnel, and collect about 15 milliliters in the test tube. Pour this water into the watch glass or saucer and let it evaporate. The evaporation may be speeded by putting the watch glass over a beaker of boiling water. A saucer should be set in a warm place without heating. Put an equal amount of tap water into a similar dish for control. As many soil samples may be tested as desired.

What was observed: What collects on the glass when the water has evaporated? How much material collects on the control dish as compared with the ones containing soil water?

What was learned: Does the soil sample tested seem to contain much soluble mineral?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: humus, clay, sand, silt, loam, freezing, chemical, soluble, potassium, nitrogen, calcium, phosphorus, fertilizer.

9. How can we conserve the soil?

There are two problems of soil conservation. The first is concerned with the wise use of soil; the second with methods of preventing its erosion.

How may erosion start? Erosion occurs at any point where the covering of the soil is removed sufficiently to permit water, wind, or weather to act directly on the soil.

The covering of the earth has been removed by man in cultivating the soil, in cutting the forests for lumber, and in clearing land for agricultural use. Many animals destroy the protective plant covering. Grasshoppers leave the soil bare of plants. Prairie dogs dig deep holes in which erosive forces act. Sheep and cattle graze so closely that they destroy the grass. Many grazing animals, particularly deer and sheep, eat small shrubs and trees.

Fire is the worst of all destroyers of the plant cover of the soil. A single fire may destroy a forest many square miles in extent, killing trees that may not be replaced in one or two hundred years.

The importance of plants in protecting soil can hardly be overstated. Their leaves break the force of rain. Leaf mold holds water. Plants break the force of wind, preventing soil from being blown away. Trees shade the snow in spring and prevent rapid melting and runoff. Roots of trees and plants may serve to hold soil and stop the formation of gullies.

There is hardly a large section in the United States where erosion is not a genuine threat to our food supply.

What are the commonest types of erosion? Running water is of course the greatest erosive agent. During a heavy rain, water often runs in a sheet over a field and removes a thin layer of soil from the entire field. The more sloping the field, the greater is the amount of soil that is removed. It is a common observation of farmers that hilltop and hillside fields are not as fertile as the lower lands. In fact the term "rich bottom lands" is a typical way of recognizing this difference. The fertile soil from the hills has been washed down into the bottom lands. Much fertile soil is carried into the streams and is lost. If you have seen a stream flowing through a plowed field and another flowing through a sodded meadow, you can well appreciate the loss of soil by rain erosion. The water in the first stream is brown, that in the second crystal-clear.

Gully erosion results when the water forms small valleys. A gully is really the beginning of a young

U.S.D.A.

At the top of this gully are the remains of a cornfield. Has the gully been formed suddenly or over a number of years? Gullying is an extreme form of erosion but not an unusual one.

valley. While it is true that it is the lifework of a stream to wear away and drain the land, the problem becomes serious if you happen to own the land and depend upon it for a living. And all of us really depend upon the land for a living. A gully may start in a small footpath, spread into a neighboring field, cut a wide hole in the field, wear itself deeper, cut back until the field is destroyed, undercut its banks causing the farmhouse and barn to fall into the hole, and destroy the farm so completely that it is unfit even for growing trees. Similar erosion happens not to one but to hundreds of farms. In many of the hilly regions of southeastern United States, where originally the land was fertile, there are practically no farms capable of supporting their owners.

Stream erosion occurs continually along all streams. It is most destructive of farm lands in flood season. Streams may deposit deep layers of sand and gravel over productive land and spoil its fertility. They may wash away trees and other vegetation and remove all the fertile soil.

When occasionally rain falls in deserts, erosion is more rapid there than in moister regions. There is little protective vegetation in deserts. Because most of the deserts in the United States are situated in elevated regions, the runoff is rapid and destructive.

Caterpillar Tractor Company

Proper cultivation prevents erosion and loss of water. The upper field has been cultivated to form ridges which hold snow needed for moisture. The lower field retains a heavy rainfall which under poor cultivation would have run off, leaving gulleys and dryness behind.

Wind erosion has been a problem in some regions since the last glacier melted. Where drought kills native grasses or cultivation removes them, the bare soil is blown like snow, forming drifts, darkening the sky, sometimes choking and smothering animals, and destroying the value of the land. The desert states and dry states of the Southwest are most troubled by dust storms. Wind erosion can destroy the value of a farm in two or three years.

How is erosion controlled? Probably the most important single means of erosion control is through proper cultivation. There are many ways of cultivating soil to retard erosion. For example, if a hill is plowed in such a way that the furrows run from top to bottom, each furrow acts as a small valley down which water can run, carrying soil with it. If, on the other hand, the plowing follows the side of the hill, so that the earth is thrown up the hill and each furrow maintains the same elevation around the

Minneapolis Moline

Returning barnyard and animal wastes to the soil is an important aid in maintaining its fertility. Removing these wastes immediately to fields also improves sanitation around the barns. The machine is a spreader.

hill, the furrows act as dams. This method is called contour plowing. The water is held behind these dams until it has a chance to soak into the soil. Where a gully has started, a ridge of soil may be thrown across it to retard the flow of water. Since sediment settles in still places, every quiet pool, however small, is a soil saver.

On steeper hillsides, the soil may be terraced. There are regions in China and in the Philippine Islands where rice fields are terraced. The fields lie one above another like stairsteps. Terracing requires work and engineering skill to prevent the edges of the terraces from becoming waterfalls which speed up erosion. The terraces, if properly placed, may be made of earth. In the steepest places stone, wood, or concrete may be used to hold the soil.

All fairly steep slopes should be planted in some permanent crop, preferably a perennial of the clover or alfalfa type, which will form a deep root system and remain in place for years. If such crops will not grow on the soil, it should be planted to some native grass or to shrubs which will provide protection for birds and wild game. Most slopes can be converted eventually into wood lots.

Grazing should be carefully controlled. Before the ground is bare of grass, cattle should be removed to other grazing grounds. Fires should never be started where erosion might result.

Gully erosion may be stopped by cutting down the sides of the gully and planting them with trees and shrubs. It may be necessary to build stone, wood, or brush dams where the slope is too steep for plants to grow.

In small streams use of dams equalizes the water supply and causes all sediments to be depos-

Standard Oil Company of California

Conserving fence posts by use of a chemical preservative saves both wood and the labor of setting the posts.

ited. Building large dams stops the cutting of a river into its valley and slows the cutting of side streams. In forests where enough trees are available, beavers are among the best erosion-control agents. They build dams which cause lakes to form. These lakes fill up and become wide meadows. Since beavers eat the bark of trees, they are of value only where there is enough food for them without destroying valuable timber.

It is the responsibility of the state to provide experts to inspect farms and to educate farmers as to the need of controlling loss of lands. The state can well afford to supply trees to farmers. The federal government has made direct payments to farmers who plant erosion-controlling crops on their farms. While it may be the course of natural events for solar energy to wear away the earth, it is our responsibility to protect those parts which we need. The soil contains our most valuable mineral wealth. Already, too much of it has gone down to the ocean, where the plant food is dissolved, and the soil settles to form sedimentary rocks for future ages.

Exercise

Complete these sentences:

Wearing away the land and transporting solid materials is

called —1—. A major factor in causing it is man's —2— of the soil. —3— destroys the humus in soil. —4— by animals may cause erosion. Washing a thin layer of —5— from fields is the cause of barren hilltops. A small valley formed in soil is called a —6—. In dry countries erosion by —7— occurs. If land is —8— around hillsides, washing is slowed. Continuous cover should be provided for all —9— ground. Use of —10— in streams reduces erosion.

10. How can we best use natural resources?

Conservation is not the simple problem that some people believe it to be. Too often a small problem of conservation is allowed to overshadow the larger problems. For example, some people concentrate their attention on protecting wild ducks. Others are interested in preserving natural scenery. Still others are interested in making as much money as possible from natural resources with the least effort.

Responsibility for wise use of materials depends upon two large groups of people, the producers and the consumers. In some cases the producer is the government —all of the people acting through their representatives to control public lands. In some cases the producer is a manufacturer, miner, lumberman, cattle grower, or farmer. The owner of a garden plot or a lawn is a producer. Everyone is a consumer in proportion to his wants and his income.

Can production of goods be improved? A producer has the responsibility of producing the best possible article from the materials available. The cattle grower should produce the best beef that can be grown. The potato grower should produce only good potatoes.

The responsibility of a manufacturer includes several steps. After it has been decided that there is a demand for an article the first problem is one of designing it. The second is to arrange for a supply of materials. The third is to build a factory and put into it the machines which make mass production possible. The quality of the materials and workmanship must be controlled at all times.

The importance of design can hardly be overestimated. In a way it is perhaps fortunate that in the past articles have not been made more durable, for their design generally has been capable of much improvement. The design of an article determines in large part whether or not it will be durable, however.

Tests of good design are not easy to make. The first test is to decide whether or not an article actually does the work required of it. A toaster should toast each slice of bread evenly and should

Missouri State Chamber of Commerce

Chemical analysis and control make it possible to use clay for making fire bricks for lining furnaces.

toast each slice equally well. A lamp, to be well designed, should distribute light where it is needed. The second test of good design is to determine how long an article will last. Many articles we buy do not last long enough. Many toasters will not withstand being dropped from the table. An alarm clock can be made which will last 10 to 20 years, and by adding more costly materials one could be made which would last 100 years. Many alarm clocks never run accurately and soon will not run at all. These two tests—proper functioning and durability—could be applied to most manufactured articles we buy.

When a good article has been designed, it still is necessary to make it convenient and attractive to use. An automatic toaster is much more convenient to use than one which must be watched. Its covering should be durably smooth and shining. It should be so designed that crumbs can be removed from it easily. It should be possible to move the toaster or remove the toast without burning the fingers. A toaster should be free from electrical shock hazard.

Designers naturally do not arrive at perfect answers to all problems at one time. But each designer has the responsibility of making each new product better than any that has been sold before. It is a common practice to build equipment so that it will wear out, in order to make its repair or replacement necessary.

The choice of materials is determined in part by cost, and in part by convenience in using them. Sometimes an excellent article may be designed, and no way can be found of producing it at a price which people will pay. Too often an article is deliberately made of inferior materials to save a very small part of the final cost. In making a toaster the metal cover sometimes is assembled by bending small strips of one part through slots in another part. This flimsy construction is not strong, and the cover cannot be removed and replaced when it is fastened in this way. The heating unit of a nonautomatic toaster should be the only part which wears out and it should be replaceable. Use of lasting mate-

rials is only slightly more expensive than is use of flimsy materials.

In an alarm clock the hardness of the metal in the bearings—those places where parts move against each other—determines how long the clock will be accurate. The toughness of the steel in the spring is an important determiner of how long the clock will run at all. The accuracy with which the parts are made in the first place determines whether or not the clock will keep time when new.

These examples will help you to understand the problems of manufacturing good articles. Money spent on design and on materials determines the value of the article.

Can consumers use goods wisely? In general most families spend most of their incomes for consuming various kinds of goods. The kind and amount of goods bought is determined chiefly by the size of the income. Quite generally conserving materials is only indirectly considered in family purchases.

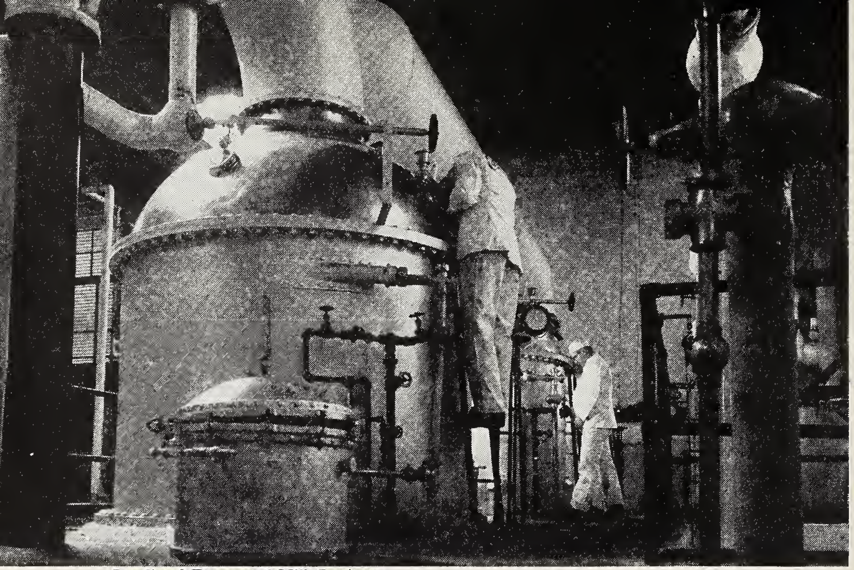
Good buying practices and good conservation actually do go together. The wise buyer will first try to determine whether or not he actually needs and wants an article. By waiting and careful study many purchases originally considered will not be made. Stores are planned to make people buy according to whim. You should rarely buy anything not on a shopping list planned in advance.

Science Service

This model oil pump is of the type commonly used in obtaining oil from fairly shallow wells. Can you make one like it?

When it is determined that an article is to be bought, the next problem is to buy the best one available. This is not necessarily the one which is highest in price, for price is only slightly related to quality of manufactured articles. Only careful study of science, of consumers' magazines, and of the articles themselves will help to decide this. Educated consumers can force poor-quality products off the market and can thus conserve materials.

The third problem is to make the article render good service. In the case of clothing style may determine length of service, but for most things style is not too important. If you buy a post for your clothesline it will last perhaps three years if it is put di-



Irradiated Evaporated Milk Institute

In these huge vacuum pans the air pressure is reduced to make possible evaporation of water from milk without heating it too much. The reduced air pressure lowers the boiling point in making evaporated milk.

rectly into the ground. If it is treated with creosote or some other preservative and set into a block of stone and concrete it may last 10 to 15 years.

When an article has served its usefulness, it still may be used by some other person or it may be used for materials for some other purpose. For example, waste rags are used for making roofing.

Exercise

Complete these sentences:

The —1— an article includes all plans for making it. How well an article does its work may be called a test of proper —2—. How long it lasts is a test of —3—. The difference in final cost between good and poor materials is —4—. An article must be designed so that it can be made by —5— methods. Only those things should be —6— for which we have actual needs and wants. The articles bought should generally be the —7— available. The use to which an article is put is determined by the —8—. Good buying is actually good —9—.

A review of the chapter

Conservation is the saving or wise use of natural resources. Some things, such as running water, wind, and sunshine, are lost if we do not use them. Many materials may be replaced as used, and the

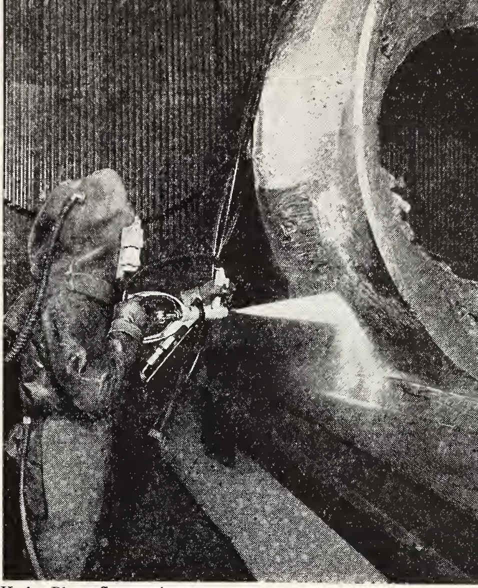
supply will last indefinitely. Many minerals, particularly oil and some metals, are scarce, and are irreplaceable. We can make the supply of irreplaceable materials last longer by using them only for essential purposes, by re-using those which are durable, and by substituting for them replaceable materials.

We depend upon natural resources not only for materials, but also for energy and for our plant and animal resources. Soil is perhaps our most important single source of minerals. Soil can be conserved only by using it in such a way that its value is protected and its minerals constantly replaced.

Producers have the important responsibility of making only well-designed and durable products. Consumers have the responsibility of rejecting inferior products and buying the good ones. Consumers also have the responsibility of obtaining the best possible service from products they buy.

Science has enabled us to develop from our natural resources many useful chemicals and other needed materials.

The word *conservation* has a more exact scientific meaning. The law of conservation of matter and energy is stated: matter and energy may be changed in form but cannot be created or destroyed. This law means that the form of matter may be destroyed, but that the matter itself and the energy involved in the change will continue to exist in some form somewhere in the universe. A forest can be destroyed but the chemicals cannot be.



Hydro-Blast Corporation

Sand is driven in a stream of water to polish the huge piece of cast iron. This is a typical physical change. Why?

Word list for study

conservation	fertilizer	by-product	B.t.u.
efficiency	gully	humus	calorie
carbon monoxide	natural resources	organic	dextrose
strip mining	petroleum	terrace	loam
salt	calorimeter	design	erosion
alcohol	shaft mining	coke	contour
cellulose	distill	uranium	

An exercise in thinking

Write the numbers from 1 to 35 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Conservation of material resources depends upon saving irreplaceable resources and upon using all materials wisely.

B. Every change in matter is accompanied by a change in the amount of energy present.

C. A chemical change produces a new arrangement or combination of atoms within the molecule.

D. A physical change produces a new condition of matter but leaves the atoms unchanged within the molecule.

E. When a substance dissolves, its molecules are held in the spaces between the molecules of the solvent.

F. Efficiency equals useful energy divided by total energy.

G. The state of matter depends upon the amount of heat it contains.

List of related ideas

1. Heat is required to make chemicals from coal.
2. Minerals used by plants are absorbed in water.
3. Whenever possible water power should be used to produce electricity.
4. Erosion generally breaks rocks into smaller pieces.
5. Plastic materials set as they cool.
6. About three-fourths of the coal burned in good engines is wasted.
7. Iron ore plus coke yields carbon dioxide plus iron.
8. Limestone is weathered rapidly in water containing carbon dioxide.
9. Acids react with most metals to form salts.
10. Linseed oil is obtained by pressing flax seeds.
11. Burning coal is our most common way of obtaining heat.
12. Sulfur may be forced from the ground as a liquid when melted by superheated water.
13. Only about half the heat of coal warms our houses when it is burned.
14. Coal should be used to provide chemicals only when plant materials are not available.
15. Boiling a sample of soil in water removes some minerals from it.
16. Every manufactured article should be designed as well as present knowledge permits.
17. The breaking up of the nucleus of the atom releases several kinds of radiations.
18. Only energy which produces desired changes or does work is of use.
19. If boiling water and steam are both at the temperature of 212 degrees F. the steam contains more energy.

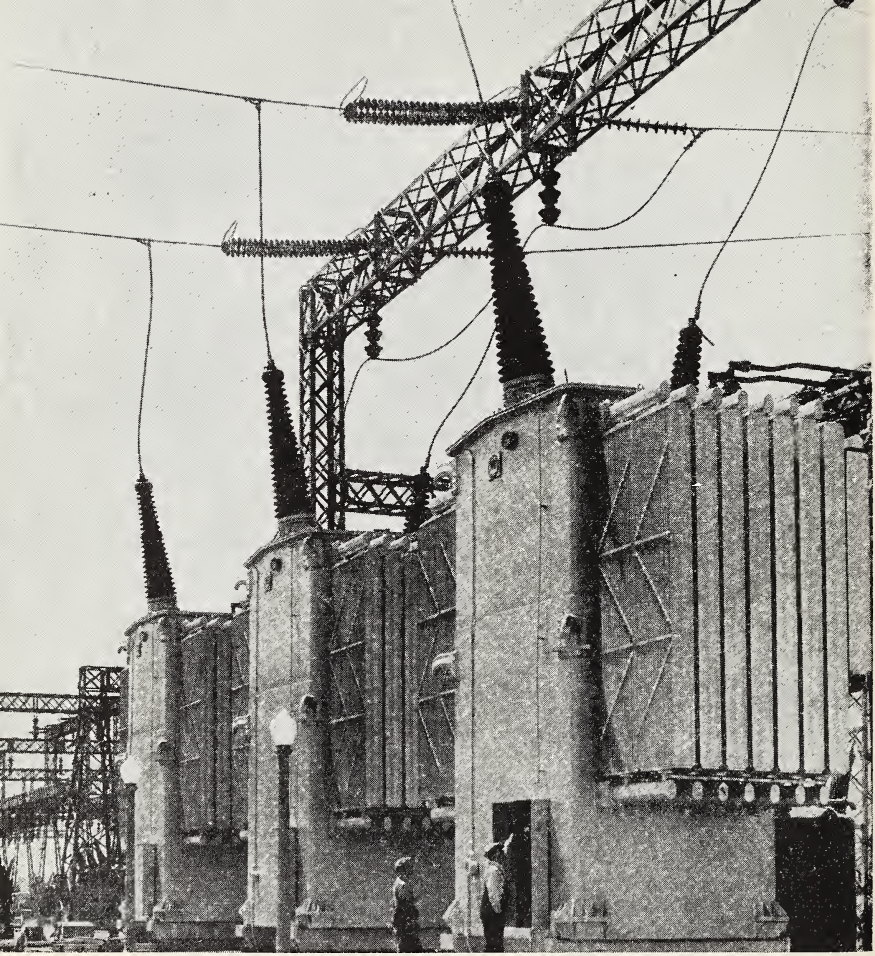
20. Gravity separates iron and slag in a blast furnace.
21. Mercury in a thermometer expands when heated.
22. Fermentation of sugar produces alcohol and carbon dioxide.
23. A B.t.u. is the amount of heat required to raise one pound of water one degree Fahrenheit.
24. A good water turbine may convert 90 per cent of the energy of falling water into work.
25. When a solution containing alcohol is distilled it is heated and the vapor is cooled.
26. When coal is burned without sufficient air carbon monoxide is formed.
27. Iodine crystals disappear in alcohol but produce a dark-brown color.
28. Sloping hillsides are best used for trees and grass.
29. Ink, bluing, and household ammonia are mostly water.
30. Lathes are used to make pieces of metal round.
31. Compressed gas causes oil to flow in some oil fields.
32. When mercury is heated in air it combines with oxygen and forms a red powder.
33. Every article we buy should be used as long as practicable.
34. Granite rock separates into sand, clay, and mica when weathered.
35. Water gives off heat as it freezes.

Some things to explain

1. Discuss this statement: The average woman uses more applied science in the home than the average man does at his work.
2. Why is coal the most important source of energy under our control?
3. Why is conservation of plants and animals so closely related to soil conservation?
4. Is there good reason to believe that the earth in the future will have fewer rather than more people on it?
5. What education and training should one obtain to become an industrial designer?
6. Why is it unlikely that alcohol will replace gasoline as a cheap and efficient fuel for automobiles?
7. How is the atomic age developing at present? What are some industrial uses of this energy?

Some good books to read

Building America, *Power*
Chase, S., *Rich Land, Poor Land*
Floherty, J. J., *Flowing Gold*
Foster, W., *Romance of Chemistry*
Jaffe, B., *New World of Chemistry*
Metcalfe, J. M., *Copper*
Schoenen, H., *Story Behind Steel*
Shippen, K. B., *Great Heritage*
Stokley, James, *Science Remakes Our World*
Van Hise, C. R., *Conservation of Our Natural Resources*



UNIT TWO

ENERGY IN USE

Harry stood behind the demonstration table, on which were several shining objects. He began his remarks with, "I hope that this experiment does not prove so hilarious that we forget to learn some of the scientific ideas involved in it. I am going to show you how anyone may look like a warped personality."

He picked up a sheet of shining metal, and explained, "This is a chromium-plated brass squeegee plate. It is ordinarily used for drying photographs to produce a glossy finish. But now I am first going to use it as a concave mirror. Observe carefully what I do."

He turned his back to the class, and held the metal plate in such a position that the pupils could see his image on its bright surface. Slowly he bent the ends of the plate so that its center curved away from him. His image became wider, and one ear suddenly seemed to be considerably longer than before. The class laughed.

Harry said, "You need not laugh. You look just as funny to me as I do to you. Since you have seen me suddenly seem to grow fatter, observe how I use a convex mirror to become much thinner looking."

He then curved the plate in the other direction, and his image became very slender. Again the class laughed.

Harry explained, "I got the idea for this experiment from the crazy mirrors in the fun house at the amusement park. Crazy mirrors are made up of combinations of concave and convex cylinders of glass. Now I think the best way to continue this experiment is to pass around various objects and let you experiment for yourselves."

He handed to various pupils a shining coffee-maker, a large spoon, a curved ash tray, an automobile hubcap, a curved mirror, and the squeegee slate.

CHAPTER

3

Electricity and Its Uses

Most of us are so accustomed to using electricity that we can hardly imagine getting along without it. Only 70 or 80 years ago most people read by the light of kerosene lamps, used irons heated on the stove, and washed clothes on a washboard or in a hand-operated washing machine. They kept cool by fanning themselves with palm-leaf fans and waited for news until the newspaper arrived. Most women cooked on coal or wood ranges, and waved their hair by heating a curling iron in the chimney of a kerosene lamp. Many of these common tasks are done today with the aid of electricity.

Even where people do not have electricity in their homes they may have telephones and radios operated by batteries or by electric wind chargers. In many places the ordinary radio is so old-fashioned that people are replacing their living room sets with combination radio and television receivers. Sixty years ago radio was only an idea, and television was not even considered as a practical matter.

Today there is scarcely an occupation in which some knowledge of electricity is not required. The modern house is well equipped with electrical equipment, and the housewife who does not have some understanding of its proper use can encounter serious trouble. Hair dressers use electrical equipment. Even bookkeepers today do much of their work on electrically operated machines. Poultrymen, dentists, cooks, nurses, and factory workers use electricity to help with their work. Electricity thus has become one of the important sources of energy in modern living.

Some activities to do

1. Plate an iron nail with copper by dipping it into a solution of copper sulfate.

2. With a white cent and a copper cent make an electric cell. Put between them a circle of blotting paper

soaked with salt water. Connect the cell to a flashlight lamp to see if it will glow.

3. Make an electromagnet by winding a large nail with doorbell wire. Use it to magnetize a piece of steel spring, and make a demonstration table-size compass.

4. Hold the end of a flourescent lamp against a ground, such as a pipe, and shuffle your feet on a rug in a dark, dry room. Hold the other end of the tube in your hand. Or rub the lamp tube against a wool garment. See if you can light the lamp.

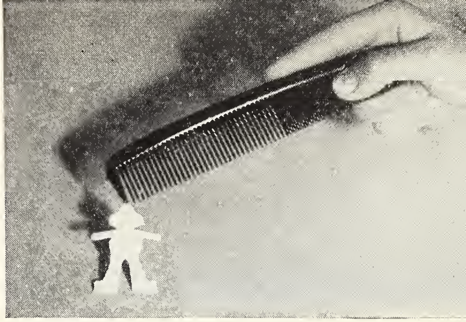
5. Bring a storage battery tester to class and demonstrate how it works.

6. Make a simple galvanometer. Obtain the inside of a match box, a small compass, and some insulated doorbell or armature wire. Wind 50 to 100 turns of wire around the box. Put the compass inside the box. When a small current flows through the coil of wire, the compass needle will turn. Experiment to find how to use it best.

7. Clean your silverware by electricity. Dissolve a teaspoonful of each salt and soda in a quart of hot water in a bright aluminum baking pan. Put the silver in the hot solution. As soon as the silver is clean, polish it with a soft cloth and a little whiting. The action of the metals and the salt produces the same type of chemical action in the pan that occurs in the wet cell and destroys the tarnish by electrical action.

8. Visit a battery charging or reconditioning plant to learn how commercial storage batteries are handled.

9. Make a simple motor. You can obtain kits at the dime store or make your own, following instructions found in books on mechanics for boys.



If you charge a rubber comb by running it quickly through your dry hair, it will pick up bits of paper. Why does lint stick to a photographic film that has been brushed against wool?

10. Make a simple electric buzzer. You may either design your own or find plans in magazines of simple mechanics.

11. Make an electromagnet, and devise experiments for its use. Make a magnetic field as follows: Dip a sheet of paper in hot paraffin and cool it. Put it over the magnet and scatter iron filings or finely cut steel wool on the paper. (*Take care not to get slivers of steel in your fingers.*) When the filings are arranged to show the field, heat the paper gently. The filings will sink into the paraffin and stick.

Make a blueprint of a magnetic field. Use reference material for information.

12. Cut figures of dolls from tissue paper, and weight their feet by pasting bits of cardboard to them. Put them in a cigar box, and cover the box with celluloid. Rub the celluloid with wool cloth, and the figures will stand up. Why?

13. Make a model transformer. Do not attempt a working model unless you are willing to do much study.

14. Learn to read your electric light

meter. Keep accurate records of the current you use, and check the light bills.

Some subjects for reports

1. The local power plant and how it makes electricity
2. St. Elmo's fire and other strange forms of electricity
3. Lightning and protection from lightning
4. Living things which produce electric currents
5. The world's largest electric generating plants
6. Generating electricity by use of wind
7. Midget dry cells

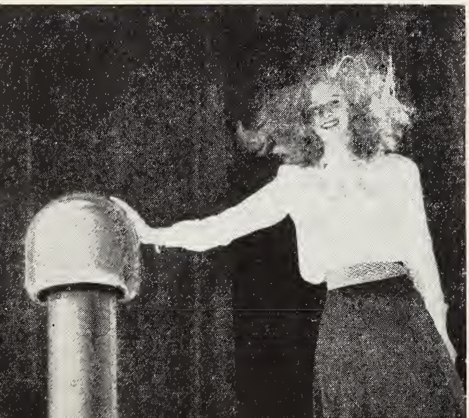
1. What is electricity?

Electricity is a form of energy. It can be used to do work, to heat wires and coils, to bring about chemical changes, and to give off light. We know enough about it to describe its behavior, to produce and use it, to measure it, and to weigh electrical charges.

What is static electricity? About 2500 years ago someone discovered that if amber [a yellowish, fossilized resin] was rubbed with silk, the amber would attract and hold small bits of paper or plant pith. From this experiment the word "electricity" was derived, for the Greek word for amber was *elektron.* The electricity produced by this experiment today is called static [stăt′ĭk, standing still] electricity, because it is stored in a nonconducting material.

As the girl touches the dome of the electrostatic generator a charge of static electricity causes her hair to stand on end.

Brookhaven National Laboratory



A rubber comb run briskly through the hair produces static electricity. The comb is charged because the rubbing dislodges electrons which collect on the comb, and the electrical balance is upset. When an object has too many or too few electrons, it is charged. Electrons are charges of negative electricity.

If you hang two balls of dry plant pith from silk threads and charge them by touching them with a charged comb, they repel each other. If, after they are charged, you hold near them a glass rod which has been rubbed with silk, they swing immediately toward the glass and cling to it.

The comb has a negative charge. When the two pith balls are charged with negative electricity from the comb they repel each other. The first part of the law of electrical charges is: *Like charges repel each other.*

The glass rod is charged with positive electricity. The negatively charged pith balls are attracted to the glass rod. The second part of the law is: *Unlike charges attract each other.* If the two pith balls are charged positively by touching them with a charged glass rod, they will again repel each other, and will be attracted by a charged comb.

An object may accumulate enough charge that sparks will be produced. Where the air is dry, you can produce an electric spark by first sliding your feet along the rug and then touching a piece of metal, such as a drinking fountain or lamp. When you charge your hair by combing it, it may stand up, for the electrically charged hairs repel each other. Sparks can sometimes be seen when a cat's fur is stroked in the dark.

From leather belts used to operate machines, sparks of static electricity may leap for a distance of several inches. Such sparks are quite painful if they strike the skin. They may also cause explosions if there is an explosive mixture of air and fuel gas or of air and vapor of alcohol, gasoline, or kerosene present.

The upper air contains static charges resulting from magnetic storms on the sun. Cosmic rays and other forms of radiation cause the upper air to become charged. Probably no electrons reach the earth from the sun, but its radiations can set electrons free in the atmosphere. Such charges sometimes become powerful enough to disturb telephone, telegraph, and radio communication.

The most exciting display of static is lightning. The friction of the air causes raindrops to become charged, and the charged raindrops break up into smaller drops, separating the balanced electrical charges into unbalanced charges. When there is a sufficient charge—one equal to billions of volts—electrons leap from one cloud to another or from the cloud to the ground. The spark produced expands the air and then the air rushes back into the partial vacuum created by the spark. The resulting noise is thunder.

What is an electric current? An electric current is a flow of electrons along a conductor. A conductor is any material which will carry electricity. If sufficient electrical pressure is applied, almost any material, even dry air, is a conductor. But such materials as copper, silver, and aluminum are generally used to carry currents.

A current flows only when there is a difference in the electrical pressure between two points. If you connect the posts of a dry cell with a wire, a current flows through the wire. The electrons flow from the post on the outside, which is the negative post, to the center post, which is the positive post.

Before scientists knew how moving electrons produce a current, it was decided by Franklin to indicate that current flows

from positive to negative. Most books on electricity now show the current flowing from positive to negative, though the actual movement of electrons is in the opposite direction. When the direction of flow makes any difference, it will be made clear to you in this book which way the electrons move.

A current can be produced in several ways, by use of cells, by use of magnets and moving coils of wire, by the photoelectric cell, by heating certain joined metals, and by connecting bodies charged with static electricity.

Most of our light and power current is produced by the use of coils and magnets in machines called dynamos. Dynamos may make either of two kinds of current: direct or alternating. In a direct current, the electrons always move in one direction. They may move steadily or in surges, but they always move in the same direction. In an alternating current, the electrons move alternately in one direction and then in the other. These two kinds of current are abbreviated DC and AC. The light current is usually alternating and makes 60 complete changes per second. These complete changes are called cycles.

The electric cell is a source of a direct current, such as is used for flashlights.

The photoelectric cell consists of a metal or compound, which gives off electrons when light shines upon it, and a metal plate which collects the electrons. It is used for measuring light for photography and for testing strength of illumination. The thermocouple is made of two kinds of metal in close contact with each other. When the coupled or joined metals are heated, a small voltage is generated and measured by a sensitive meter. It is used for measuring temperatures in furnaces which would melt or break ordinary thermometers. The current is caused by electrons passing from one metal to the other.

Electric currents are much commoner than most people suppose. Tiny currents flow in your nerve cells. Each cell in living organisms seems to have a positive and a negative end. Electricity seems to be one of the chief forces of life. An electric eel found in South American waters gives so strong a shock that it can disable a man.

Currents set up in the ground corrode the metals of water and gas pipes. When one's mouth contains gold and silver fillings, a small current is produced in the mouth. A current is produced in any solution containing an acid, base, or salt and two unlike metals.

DEMONSTRATION: WHAT IS ELECTRICITY?

What to use: Glass rod, silk, hard rubber or ebony rod or comb, wool or fur, pith balls suspended from thread, sulfuric acid, water glass, copper and zinc strips, wire, nail, compass, doorbell.

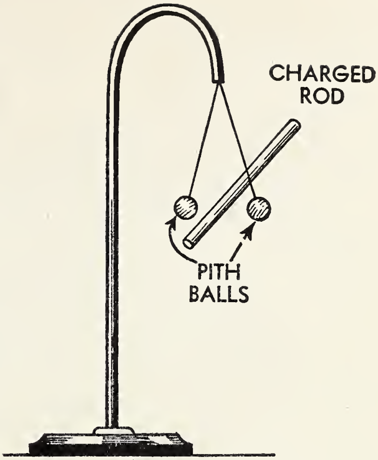
What to do: Suspend the pith balls as shown in the diagram. Charge the

ebony rod by rubbing it with the fur, and charge the balls by touching them. Repel the pith balls as shown in the diagram. Repeat the experiment, using the glass rod charged by rubbing it with silk.

Pour one part sulfuric acid into ten parts water in the glass. Stir the water as you mix the acid in it. Insert the copper and zinc strips. Wrap a nail with insulated wire, and attach the wire to the strips. Try the electromagnet you have made to see if it will lift a pin. Repel and attract the needle of the compass.

What was observed: Describe in detail what you observed in each part of the experiment.

What was learned: State the law of electrical charges, and give proof as observed in the demonstration. State one way in which a current may be made, and state one result of using a current.



When rod and pith balls have the same charge, they all repel each other.

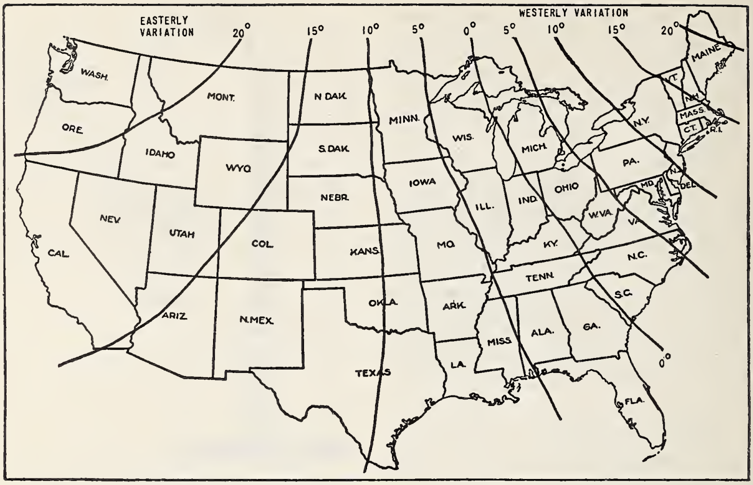
Exercise

Complete these sentences: Electricity is a form of —1—. Negative electrical charges are called —2—. Static electricity accumulates in —3—. Lightning is —4— electricity accumulated in —5—. An electric current is a flow of —6— along a —7—. Five ways of producing a voltage are by —8— and coils, by connecting charged —9—, by —10— changes, by use of the —11— cell, and by heating joined —12—.

2. How is electricity related to magnetism?

More than 2000 years ago it was discovered that a certain iron ore, magnetite, had the power of attracting pieces of iron. When a small piece of this ore or magnetized iron was used for a magnet, it was called a lodestone [leading stone] because it points in the general direction of the North, or lode, Star.

What is a compass? The modern compass is a magnetized needle mounted on a pivot so that it turns easily. The earth is a magnet, with one of its magnetic poles located in northern Canada near Hudson Bay. Because unlike magnetic poles attract each other, the compass needle points toward the north magnetic pole. The compass points to true north at Cincinnati, Ohio, and it points about 20 degrees northeast in the state of Washington. Allowance



This map shows the approximate differences between readings of magnetic north and true north in the middle 1940 period. Because the north magnetic pole shifts, this kind of map must be constantly changed.

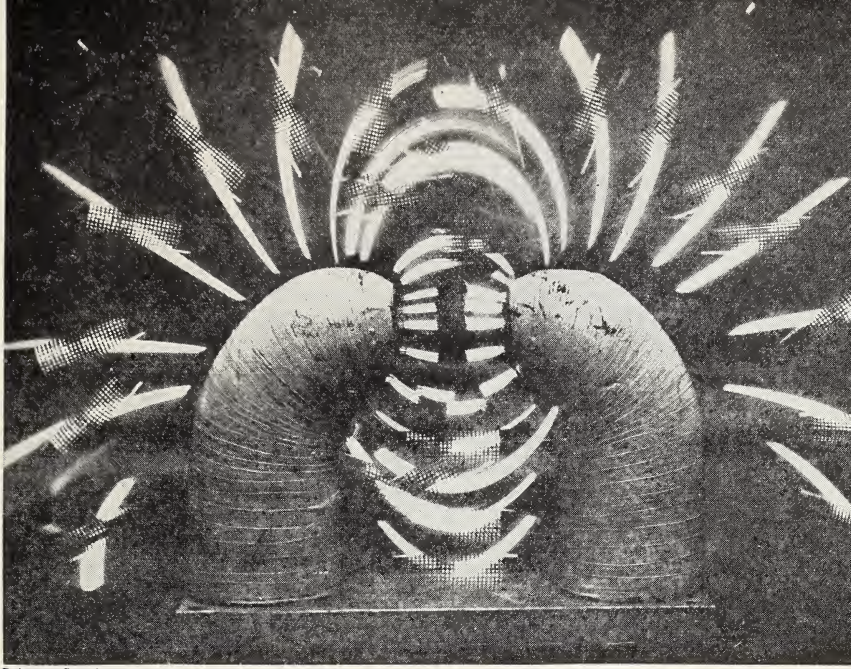
must be made for the difference between magnetic north and true north when one uses a compass. The north magnetic pole moves about slowly so that it is not too dependable a guide.

The compass used in navigation is made up of a magnet attached to a cardboard disk on which the directions are marked. The card is mounted on a pivot, and may turn freely. Some compasses are mounted in liquid and some on pairs of rings so arranged that no matter which way the ship rolls, the compass remains level.

How are permanent magnets made? Permanent magnets are bars or rods of hard steel or of complex alloys. The bars may be straight or bent into a horseshoe, or U, shape. The best permanent magnets are various alloys of iron and cobalt or nickel and aluminum. Most permanent magnets are weak, but the strongest magnets will hold up more than 60 times their own weight.

An iron or steel bar may be magnetized by putting it in a coil carrying a direct current and pounding it, or by rubbing it against another magnet. The molecules of the metal, which are normally scattered and irregular in arrangement, seem to turn with all their magnetic charges lined up in one direction. The sound of molecules turning in a bar as the bar was magnetized has been broadcast over the radio.

What is magnetic force? Magnetism is a force. That is, magnetism may push or pull upon some kinds of matter. The unit of magnetic force is called a "line of force." These lines of force are



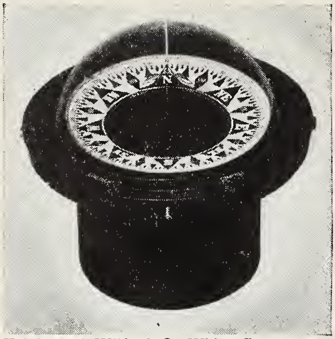
Science Service

By use of a specially designed tube, the magnetic field around a powerful electromagnet is made visible by its action on the gas in the tube. The tube was held in various positions as the photograph was made. You can locate each position of the tube by the screen which is inside the tube.

more abundant and closer together around strong magnets than around weak magnets. If two bar magnets are laid on a table and covered with glass, iron filings sprinkled upon the glass arrange themselves in closed curves along the lines of force. The total number of lines of force is called the magnetic field. The points within the magnet where magnetic force is strongest are called the magnetic poles.

Any wire or other conductor carrying a current is surrounded by magnetic lines of force. These lines of force cease to exist when the current is shut off, for they return to the magnet. Insulation of the wire does not insulate against the magnetic lines of force. If you bring a magnet near a compass, the compass is more affected by the magnet than by the earth's magnetism. The north end of the compass is attracted by the south end of the magnet and repelled by the north end. The letters N and S on magnets mean north-seeking and south-seeking. The law of magnets is: *Like poles repel; unlike poles attract.*

How are electromagnets used? As you know, an electromagnet is



Kelvin and Wilfred O. White Company

The mariner's compass depends upon a magnet to turn the card. The many points on the compass make it possible to determine direction with a fair degree of accuracy.

made up of a coil of insulated wire surrounding a rod or bundle of rods of soft iron. The iron core concentrates the magnetic fields of the turns of wire in the coil. When the current is flowing the core is similar to a permanent magnet. When the current stops, the core loses most of its magnetism immediately, and all of it eventually.

The magnetic effect of a current is one of the two most useful types of energy derived from electricity. Electromagnets form essential parts of every telephone, telegraph, radio, transformer, motor, generator, doorbell, electric razor, electric clock, and coil used in electrical machines.

Electromagnets are further used in industry in handling pig iron, waste iron, and iron and steel rods and bars. Electromagnets are used to pick up waste iron, tacks, and nails from highways, preventing unnecessary wear on automobile tires.

An electromagnet has four advantages over a permanent magnet. It can be made much stronger. Its strength may be changed by changing the strength of the current flowing through its coils. It can be controlled by opening or closing a switch. Its poles can be reversed; that is, a north pole may be changed to a south pole and a south pole to a north, by changing the direction of flow of current through its coils.

How are currents made from magnets? A voltage is generated when a magnetic field moves through or cuts a conductor, such as a coil of copper wire. The coil may cut the magnetic field or the field may cut the coil. A current produced in this way is said to be *induced*. The instant the movement of the coil or magnetic field stops, the current stops. A current flows as the result of a voltage being set up if a proper conductor is provided. Voltage may be thought of as a kind of electrical pressure.

A weak current, too weak to measure except with a sensitive meter, may be produced in the laboratory with a simple coil and magnet. The sensitive meter is called a *galvanometer*. The galvanometer is a very sensitive compass suspended so that it is attracted or repelled by the magnetic field around a coil of fine wire. If you can, make the galvanometer described in activity 6, page 125, for use in experiments.

DEMONSTRATION: HOW IS ELECTRICITY RELATED TO MAGNETISM?

What to use: Magnets, electromagnets, coil, galvanometer, iron filings, four dry cells, wire, compass, paper, and glass.

What to do: Arrange the magnets so that one can move, and repel and attract the movable magnet with the other.

Test the law of magnets by use of a compass.

Put a piece of glass or paper over the magnets, and make patterns of the magnetic field by sprinkling iron filings upon the glass or paper.

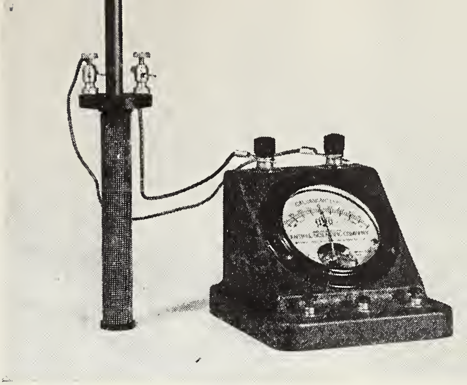
Connect a wire to the two poles of the dry cell, and hold it in different directions over the compass.

Connect the electromagnet to the cells, and put a paper over the poles. Sprinkle iron filings upon the paper, and observe how they act. Remove the paper and filings, and put a piece of iron across the poles of the electromagnet. Test the strength of the magnet by pulling upon the iron.

Arrange the coil and galvanometer as shown in the picture. Move a magnet within the coil, measuring the current with the galvanometer.

What was observed: Describe briefly what happened in each step.

What was learned: State three laws of electricity and magnetism illustrated by these experiments.



When a magnetic field cuts a coil of wire, a voltage is generated. Does a current flow when the magnet is still?

Exercise

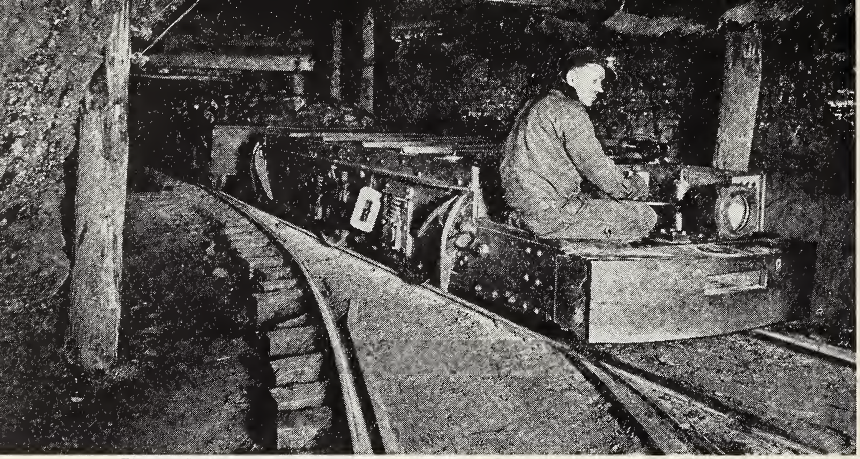
Complete these sentences:

A —1— is a natural magnet. A compass is a freely suspended —2— which indicates the direction of the —3— poles. Permanent magnets are made of —4—. Like poles —5—; unlike poles —6—. A coil carrying a —7— surrounding a core of soft iron is an —8—. When a conductor cuts a —9—, a —10— is generated which may produce a —11— under favorable conditions.

3. *How is current produced in cells?*

When you snap the switch of your flashlight, you probably do not think to yourself, "I am causing chemical changes to take place which produce a current which, in turn, encounters resistance, heating a wire which gives off radiant energy."

How do wet cells produce current? So-called dry cells are used in a flashlight to produce current. If you cut a flashlight cell, or any other dry cell, down the middle, you will find that it is a zinc can filled with chemicals surrounding a center post of carbon. You will find, too, that the so-called dry cell is not really dry



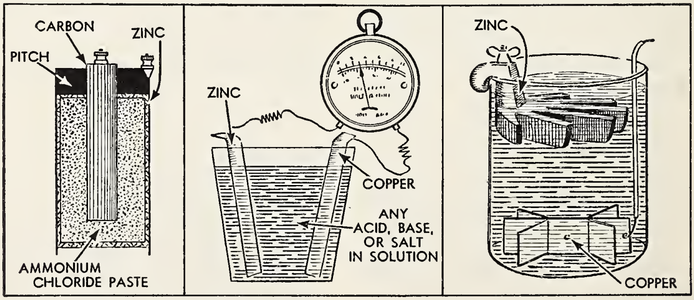
Electric Storage Battery Company

This electric locomotive used in a coal mine draws its energy from storage batteries. Such a locomotive does not give off dangerous gases and does not need a trolley.

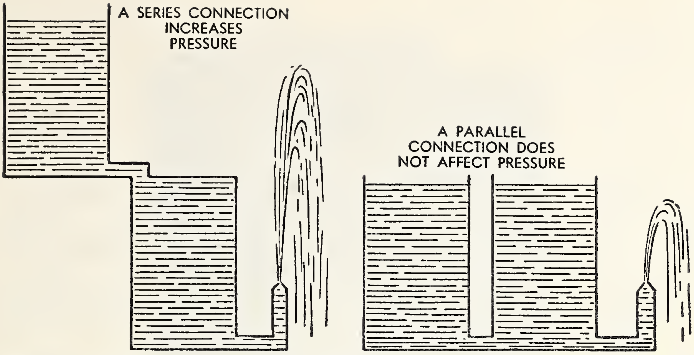
but that it contains a moist paste.

The chemicals in the cell are ammonium chloride and manganese dioxide. The ammonium chloride has electrons in its molecules which become free in the moist paste. The flow of electrons along a wire from the zinc to the carbon is a current. The current is produced by a chemical change in the cell. The ammonium chloride reacts chemically with the zinc, and the zinc gradually becomes coated with a white salt. The manganese dioxide prevents the accumulation of gases around the carbon in amounts that might stop the flow of current. The dry cell changes chemical energy to electrical energy.

A greatly improved dry cell has a center post of mercuric oxide



There are many ways of arranging the parts of a wet cell. The first drawing shows the construction of a so-called dry cell which contains a moist paste. The second shows a classroom cell. The third cell is of the type used for many years in telegraphy. It contains a copper sulfate solution.



When cells are joined in series, the voltage (pressure) is increased. When they are joined in parallel, the voltage is unchanged.

instead of carbon, and somewhat different chemicals in the container.

The dry cell is the product of many years of development of the wet cell. The simplest wet cell is made by putting strips of zinc and copper, or any two unlike metals, into a tumbler containing salt water. When the strips are connected with a wire, a weak current flows.

A better wet cell may be made by using copper sulfate in water or dilute sulfuric acid, instead of the salt solution and by using larger strips of copper and zinc. Wet cells have been used for many years in telegraphy. Some wet cells may be operated with the switch closed without losing their strength rapidly as does a dry cell.

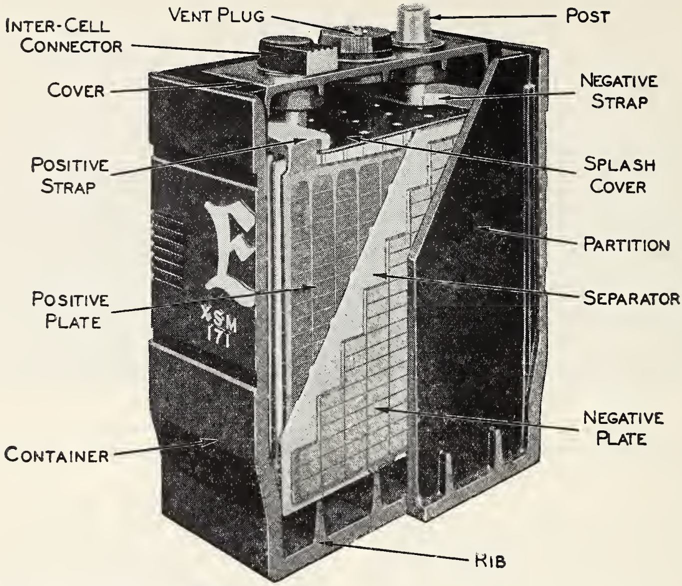
The wet cell was the first practical source of electricity, and was developed by the Italian scientist Volta. He made his first cell of alternate pieces of copper and zinc stacked in a pile. The pieces of metal were separated by cloth soaked in salt water.

When a number of cells are used together, they make up a battery. The battery of a flashlight consists of two or three cells.

If the center (positive) post of one cell is connected with the outer (negative) post of the next through a series of cells, the connection is called series.

When a current flows through a wire, it encounters resistance. That pressure or force which causes the current to flow is called voltage. Connecting cells in series increases the total voltage. If we connect two 1½-volt cells in series, their total voltage is 3 volts. The volt is the unit of measuring electrical pressure.

You may compare the series arrangement of cells with connection of water tanks as shown above. When one tank is placed on top of another, the pressure is increased in a pipe leading from the bottom of the lower



Electric Storage Battery Company

Study this diagram carefully to learn the parts of a storage battery.

tank. Voltage may be compared with water pressure.

If all the center posts of cells are connected to one wire and all the outer posts to another, the connection is parallel. Such a connection gives a more even flow of current over a long time. This advantage is desired in portable radios and in doorbells where batteries are troublesome to replace.

Dry cells are now made flat with square corners, instead of round, and in small sizes in order to pack more cells into a battery. Two hundred 1½-volt cells in series make a 300-volt battery. Such a battery may be used in portable radio broadcasting sets.

What is a storage cell? The simplest storage cell is made by putting two strips of lead into a sulfuric acid solution and charging them by connecting them to the posts of a series of dry cells. As the cell is charged, bubbles rise from the lead plates. One strip of lead soon becomes covered with a brown material, lead peroxide. When enough lead peroxide is accumulated on the plate, the dry cells may be removed and replaced by a doorbell. The bell will ring vigorously.

No electricity is stored in a storage cell. Instead, a current produces a chemical change which produces lead peroxide. The lead peroxide changes chemically to produce a current. It is

chemical and not electrical energy which is stored. If a storage cell is recharged regularly, it may be used over and over again before its materials wear out.

A standard storage battery is contained in a hard rubber or glass box or jar. Negative plates of lead are placed in the jar—all connected to a strip of lead. Positive plates of lead peroxide are placed between the negative plates and separated from them by strips of cedar wood, plastic, or porous rubber. Since there is always one more negative than positive plate, the two outer plates are negative. The negative plates are somewhat stronger than the positive plates. Each set of plates is fitted to a connection for wires. One lead storage cell produces a 2-volt current. To make a 6-volt battery, three cells are included in the battery case and connected in series.

Since a storage battery is worn out by being charged and discharged from 300 to 400 times, it is well to treat it carefully.

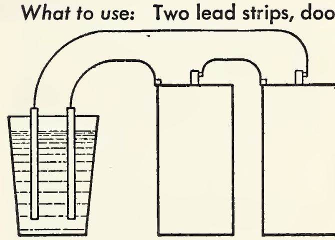
A battery is charged with a direct current. It must be kept properly charged or some of the lead peroxide of the positive plate will fall off. Overcharging also ruins a battery. When a battery is being charged, hydrogen and oxygen gases are given off, and sometimes they may be mixed in such a way that an explosion occurs.

When a battery is charged, the specific gravity of the acid solution increases. A fully charged battery gives a hydrometer reading of about 1.3 or 1300, a half-charged battery a reading of 1200. The battery should be kept full of liquid by adding distilled water as needed. Charging decomposes the water.

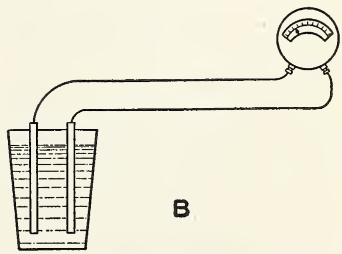
Storage batteries are absolutely essential for operation of automobiles and farm electric-light plants. Storage batteries are used also for providing current for small electric trucks in factories and for delivery of materials which might absorb odors of gasoline. Some bakeries and clothing stores deliver their goods by use of electric trucks.

DEMONSTRATION: HOW DOES THE STORAGE BATTERY WORK?

What to use: Two lead strips, door-



A



B

The charging of an experimental storage battery is shown above. The amount of current from the battery may be tested as shown below.

bell or battery tester, tumbler, sulfuric acid, wires, two or more dry cells.

What to do: First connect the lead plates to the tester or doorbell as shown in part B of the illustration. For a solution use 1 part of sulfuric acid poured into 10 parts of water. Be sure to pour the *acid into the water*.

Next, connect the dry cells in series, and charge the battery as shown in part A of the diagram. When bubbles are rising freely, test them with a burning splint. The gas which explodes with a pop is hydrogen.

When one plate becomes decidedly brown, again arrange the apparatus as shown in part B of the diagram.

What was observed: Describe the results of each of the three parts of the experiment. Why was the first part performed?

What was learned: What is stored in a storage cell?

Exercise

Complete these sentences:

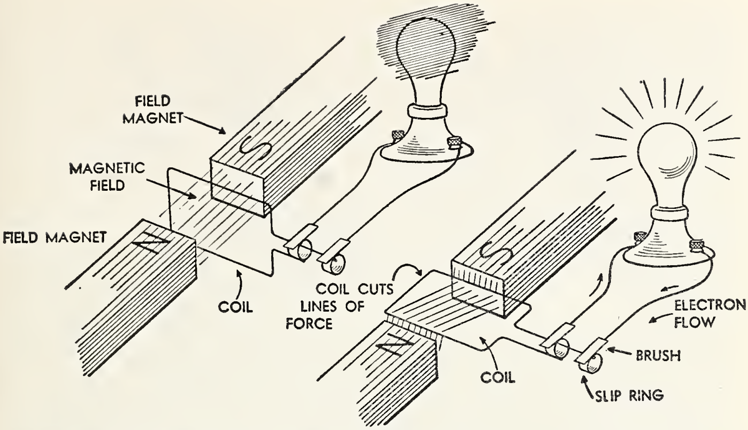
A dry cell is contained in a —1— can and has a center post of —2—. The chemical which produces the current is —3—. Wet cells may contain almost any —4—, —5—, or —6— and two strips of unlike metals. A storage battery has plates made of —7— and —8—, and contains a solution of —9—. A storage battery stores —10— energy.

4. How are light and power currents produced?

More than half the homes of the United States have some form of electric lighting. Factories, streetcars, and trains are operated by electric power. Most towns and cities have street lighting systems. The amount of energy needed for all the light and power systems of the country is so enormous that enough current could not be produced in cells or batteries.

To understand how mechanical energy is transformed into electrical energy, let us first study a system which uses water instead of electricity to transfer energy. If we have a circuit or complete system of water pipes, the water can be caused to flow around the system by installing a pump as indicated in the diagram on page 147. The pump is turned by some kind of engine. Now, if we wish to get the energy back, and not have it wasted in friction in the pipes, we may put in a water motor. The energy of the flowing water turns the motor, and work can be done.

How is an electric current made? An electrical system is in many ways similar to the water system. It is necessary to have a circuit or closed system through which the current flows. It is necessary to have some force to move or "pump" electrons through the system. And unless we put into the circuit some useful machines, the energy of the electric current is changed to heat and lost. The machine for producing electrical energy from mechanical energy is the dynamo. Special forms of dynamos are sometimes called



When the coil does not cut across the magnetic field, no current is produced. When the magnetic field is cut, a current is produced.

generators or magnetos. The dynamo is turned by an outside force, just as the water pump is. The force may be supplied by an engine, by a water turbine, by a windmill, or by any other type of machine designed to do work.

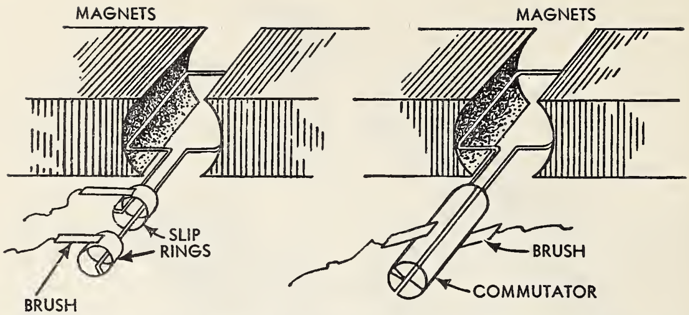
Both a water circuit and an electrical circuit must have pressure to produce a flow of energy. Pressure in water is measured in pounds per square inch. Electrical pressure, or electromotive force, is measured in volts. The rate of flow of water is measured in gallons per minute. The rate of flow of electricity is measured in amperes. The diagram shows how these measures are made by meters.

The dynamo and motor look alike in the diagram. An electric motor is different from a dynamo only in minor respects. Many motors might be used to generate current; many dynamos might serve as motors.

The outer part of the dynamo is composed of an electromagnet, called a field magnet, curved so that its poles almost encircle the rotor. The rotor consists of many coils of wires, which move through the magnetic field of the field magnets. The ends of the wires of the rotor coils are attached to rings which, in turn, are in contact with carbon or metal strips called brushes, through which the current is carried into the wires.

The dynamo usually provides current to operate its own electromagnets. The first time it is operated, a storage battery magnetizes the iron cores of the magnets. After this, there is a trace of magnetism left in the metal, sufficient to start a weak current flowing, which is used to build up the magnetism of the field magnets.

What causes the current to flow? You are familiar with the



As the first loop of wire is turned, an alternating current flows from the slip rings to the brushes. When the second coil is turned, a pulsating direct current flows from the commutator.

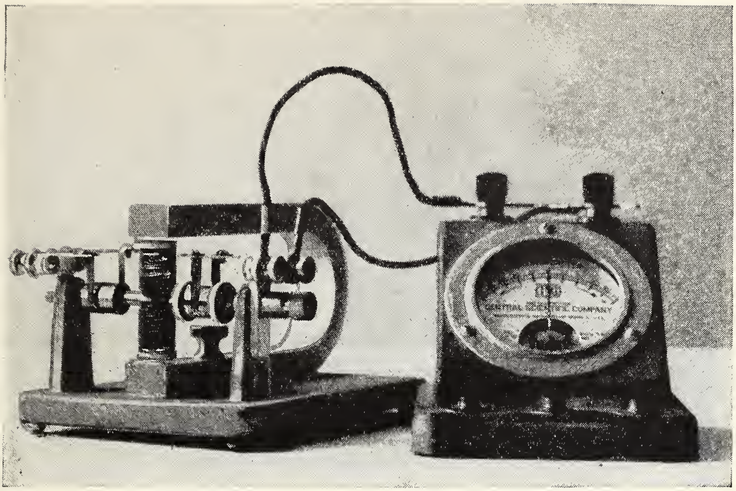
principle that when a conductor cuts a magnetic field voltage is generated which may produce a current. The dynamo works upon this principle. A current flows when the electrons in the coils are pushed along by the magnetic field.

If a coil of wire is rotated between two magnets, the current will flow one direction through half the rotation and the other direction through the other half of the rotation. Such a current, which changes direction, is called an alternating current and is delivered when the rings at the ends of the coils are two circles. Such complete circles, one on each end of the system of wires which make up the rotor, are called slip rings.

If it is desired that the current which flows from the generator shall be direct, a single ring is used, but it is split lengthwise. To each half ring, one end of the wire is attached. This device, called a commutator [kŏm′ū·tā′·tẽr], causes the current to flow from the rotor through the wires always in the same direction.

What are some common types of power plants? The steam engine, the Diesel engine, or the steam- or water-driven turbine is used to provide energy to operate dynamos for city lights. The size and number of dynamos used depends upon the amount of current needed. Several dynamos are so perfectly kept in step that alternating current from two or more dynamos may flow at the same time through a wire. Because of this accurate timing of dynamos and because there are usually several power lines interconnected, large cities are rarely without electricity, even though an accident, such as fire or lightning, may cause one dynamo to go out of operation.

The problem of farm lighting is different from that of the large city. Power from gasoline engines, windmills, or running water may be used to drive farm lighting-plant dynamos. These sources of power are not availa-



This apparatus will produce a small, direct current which can be detected by the galvanometer.

ble for steady use. Operation of a gasoline engine is expensive. Wind does not blow at all times. Water must be stored in dry seasons to last until more rain falls. Because of the uneven supply of power, it is necessary to use storage batteries.

The standard farm power plant is a direct current dynamo which produces 32 to 40 volts of pressure and which charges a series of storage batteries. The usual voltage of farm lighting systems is 32 volts, compared with the typical city voltage of 110 volts.

Cheap and rather ineffective 6- and 12-volt windmill lighting plants are sold to charge batteries for radios and to operate one or more small lamps. These plants are more satisfactory than being without electricity, but are not strong enough to supply energy for any really effective lighting system.

The automobile generator is a simple dynamo, turned by the energy of the automobile engine. It may produce current to be used directly, or it may charge the storage battery with which every automobile is equipped. Most automobile electric systems operate at 6 volts.

A magneto is a dynamo equipped with several permanent magnets. The old-fashioned country telephone, in which the bell is rung by turning a crank, has a magneto which makes the current. Small gasoline engines, such as those used for farm power and for outboard motors, depend upon magnetos to provide the spark for igniting the gasoline. These motors must be spun or cranked to start the generation of electricity to operate the engine.

DEMONSTRATION:
HOW DOES A DYNAMO OPERATE?

What to use: St. Louis or other simple motor, galvanometer, wires.

What to do: Put into the motor the permanent magnets and direct current rotor. Attach the binding posts to the galvanometer. Whirl the rotor between the unlike poles of the magnets, and use the galvanometer to measure the current produced. Whirl the rotor in the opposite direction.

What was observed: Describe how a current was produced.

What was learned: Explain how a coil and magnetic field were used to produce a current.

Exercise

Complete these sentences:

A dynamo consists of a —1— made up of coils of wire which are turned between the poles of the —2—. When the coils cut the —3— a pressure called —4— is generated, which causes —5— to flow through the conductor. The flow of current is measured in —6—. Direct current motors have —7— which take current from the rotor, while alternating current motors have —8— to do this. Dynamos convert mechanical energy into —9— energy. Most automobile systems operate at —10— volts.

5. How is electricity conducted?

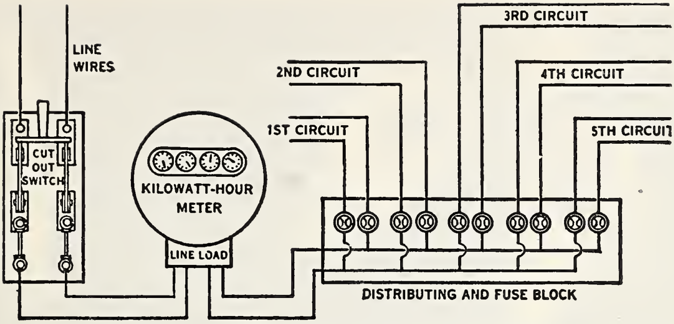
Usually electricity is carried through wires.

What is a circuit? A circuit is a closed system of conductors through which a current flows. The current flows from its source, which may be cells or dynamos, through wires and closed switches, to magnetic coils or resistance wire where the energy is given off. If the current flows through a circuit from which resistance has been removed, the result is called a short circuit.

Conductors are of metal. Although silver is the best conductor, silver wire is weak and expensive. Copper is almost as good a conductor as silver, is fairly cheap, and is durable and strong. Conductors are insulated to keep the current within the circuit. Cloth and rubber are used to insulate lamp cords. In the electric iron cord, cloth and asbestos are wrapped outside the rubber insulation. Rubber should not be used in iron cords or other conductors which are near heated bodies, stoves, and heaters. Wire may also be insulated with varnish. Varnish is thin enough to permit wire to be wound on coils with the turns close together. Spun glass and many kinds of plastics are now being used for insulation.

Insulated wires are frequently run through pipes or wrapped with steel to protect them from wear, breaking, weather, and animals.

Some circuits, such as those of radios, are very complex and require many connections. In order to save time and space many radio devices now use conductors of a silver ink printed upon a tile or plastic card. A different kind of ink is used for resistors,



The current flows into the house through the line wires. It passes through the meter to be measured. From the distributing and fuse block as many circuits lead to the house as are needed. Note that each circuit is wired in parallel to the main line wires and that each wire is connected to a fuse.

and insulation is sprayed on over the printed metal lines. With small tubes available, many radio devices may now be reduced in size.

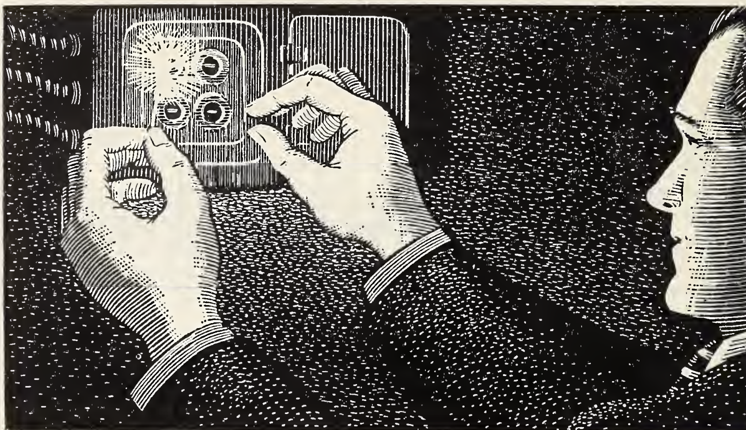
Circuits are controlled by switches. A switch contains a piece of metal which is moved to open and close the circuit. A push button or knife switch is simply a strip of metal, fitted against metal contacts, and more or less protected. Other switches are more complex and are operated by tumblers, chains, and buttons.

Knife switches are dangerous and should be handled with extreme caution. Their advantage is that they carry a heavy current without loss of energy.

How do parallel and series wiring systems compare? There are two methods of connecting electrical devices. If the current flows through first one device, then another, then another, the connection is called series. Some Christmas-tree lights are connected in series. When one lamp is unscrewed or burned out, the entire string of lights goes out because the circuit is broken. In Christmas-tree lights this arrangement has value from the safety standpoint, for if something happens to the lights the current probably will not set the tree on fire.

In house-wiring this system would have serious disadvantages. All the lights in the house would have to be turned on or off at the same time. If one burned out, it would be necessary to try replacing each one until the burned-out lamp was found. Because resistance to the current would increase each time another lamp was added, the more lamps used, the less light there would be available.

To avoid the many difficulties of series wiring, the parallel system of wiring is used. In this system, two wires are run through



General Electric Company

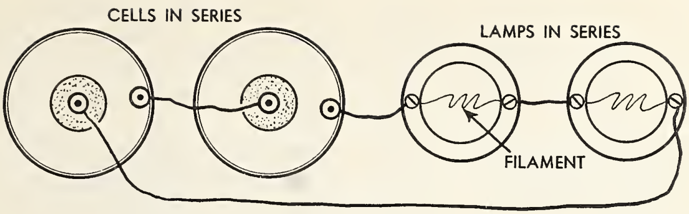
In most houses we still use fuses to protect light circuits.

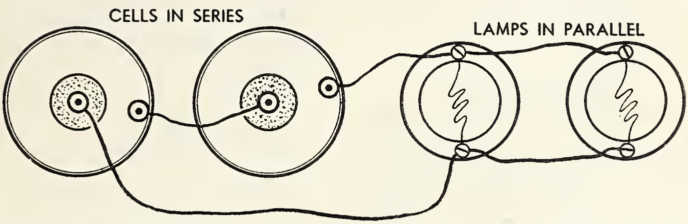
the house, side by side, each connected to the power line from the dynamos of the station. To connect a lamp, the wires of the lamp are attached to each of the power wires. Current flows across, from one wire to the other, through the lamp. Any other device may be attached at any point along the wires without affecting the lamp in any way. A toaster may be connected at another plug, a radio at another. Each uses the amount of current it needs, for each device resists the current flowing through it.

When many devices are connected in the parallel system, the current of each device comes through the power-line wires. Thus these wires must carry the total current used by all the devices in the circuit. If too many are in use at one time, the power line may be heated or the same power-line fuse may melt.

There are some systems of wiring which use only one wire. Some country telephones and automobile wiring systems are one-wire systems. One connection is grounded. That is, the earth completes the country telephone circuit; and the automobile frame completes the automobile circuit.

How do we protect against short circuits? If for any reason a current flows through the circuit without sufficient resistance, a short circuit results. If the insulation of a lamp cord is worn from the wire, the wires may come into contact with each other, and the current may flow directly from one wire to the other without going through the lamp. Without the resistance of the lamp in the circuit, a strong current flows, and the wires become hot. They may become so hot that the insulation burns, setting the house on fire. Short circuits





This is a top view of lamps in series and in parallel. Set up each kind of circuit, and learn the advantages of each system. Leave out one light in each circuit and observe what happens.

may cause serious shock to anyone who may come into contact with the wire. Wires may come into contact with water pipes or other metal connected with the ground, and current may flow into the earth, causing a short circuit.

A fuse is a device which protects our houses from destruction when an accident occurs to the circuit. It consists of an easily melted wire in a case. As you know, too much current causes wires to become hot. The fuse is placed in the circuit. When the current increases beyond a safe point, the fuse wire melts, the current is cut off, and no harm results. Fuse wire melts so easily that you can melt it with the flame of a match. The size of fuse we use depends upon the amount of current in a circuit. The unit for measuring a flow of current is called the ampere. Fifty-watt lamps use about one-half an ampere of current; irons use about 5 amperes of current. Small motors use about 2 amperes. Thus, the current used by five 50-watt lamps, an iron, and a washing machine motor added together would total about 10 amperes. A fuse which would just carry this current would melt out if another lamp were turned on.

The up-to-date method of protecting a circuit is by the use of a circuit breaker. It consists of a switch which may be opened by magnetic force. Circuit breakers can be obtained for any size for use in a home. Fuses have to be replaced, but circuit breakers are merely reset.

Correct sizes of fuses or circuit breakers must be selected to safeguard the circuit. House fuses range in capacity from 5 to 30

amperes. If you had a 50-ampere fuse in the circuit attached to your refrigerator motor, and a power line fell on your house circuit during a storm, the insulation would be burned from the coils of the motor before the fuse would melt. Replacing fuse wires with pieces of copper wire or with pennies is a dangerous and costly practice.

DEMONSTRATION: HOW ARE HOUSE LIGHTS WIRED?

What to use: Three miniature lamps and sockets, two dry cells, wire or 110-V circuit, 25-W and 100-W lamps, 2 or 3 sockets, cord.

What to do: Connect the cells and lamps in series, as shown in the upper diagram on page 145. Unscrew one lamp. Add a third lamp to the series. Observe any change in brightness.

Set up the lamps in parallel, as shown in the lower diagram. Unscrew one lamp. Add another lamp to the circuit.

Connect the 25-W and the 100-W lamps in parallel in the 110-V circuit. Turn each on and off. Next connect them in series. Turn each on and off. Note which lamp is brighter in each circuit.

What was observed: How is each system affected by turning out one lamp? How is each system affected by adding another lamp?

What was learned: What are the advantages of parallel over series wiring for houses?

Exercise

Complete these sentences:

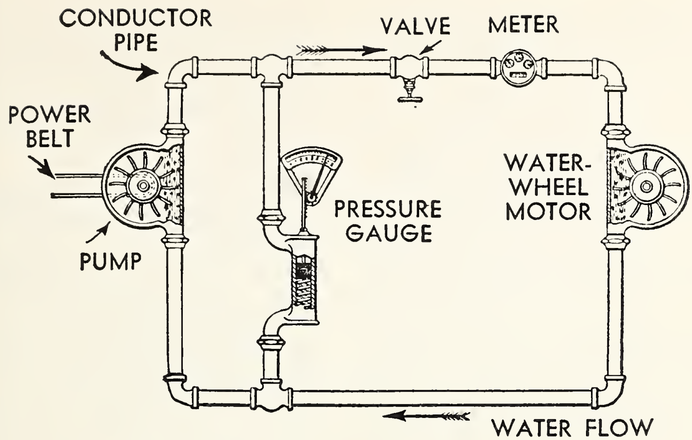
A —1— is a closed system of conductors through which a current flows. Lamp cords are insulated with —2— and —3— to prevent loss of current. The best conductor, considering strength and cost, is —4—. When the current goes through the circuit without going through sufficient resistance, a —5— results. The wire in the —6— melts and shuts off the —7—. When a circuit has only one wire, one connection is —8—. A circuit breaker is opened by —9— force.

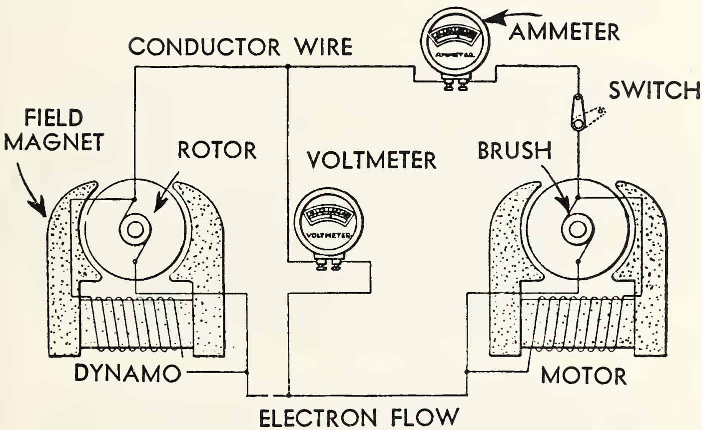
6. How is electricity measured?

When we measure the flow of water, we may measure the pressure, or the number of gallons of water which flow per minute. The flow of water is determined by the amount of water available and by the resistance to its flow in the pipes. Similarly, we can measure the flow of electricity in two ways. The pressure is measured in volts. The rate of flow of current is measured in amperes. The resistance is measured in ohms.

When we change the resistance to the flow of water by opening a faucet, we obtain a greater flow of water as the resistance to the flow decreases. We cannot affect the pressure greatly by turning the faucet on or off.

The voltage of an electrical system is determined chiefly by the device which produces the cur-





This comparison of a water system and an electrical system will help you to understand the nature of an electric current.

rent. Although voltage may drop if a circuit is overloaded, on the average house or battery circuit there is sufficient power to operate the various devices without much voltage drop. The amount of current which flows through a given device is determined by its resistance. The greater the resistance, the less the current.

What is Ohm's law? The relationship between the flow of current, the electromotive force, or pressure, and the resistance is

expressed in a mathematical formula called Ohm's law. It is:

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}$$

$$or\ \text{volts} = \text{amperes} \times \text{ohms}$$

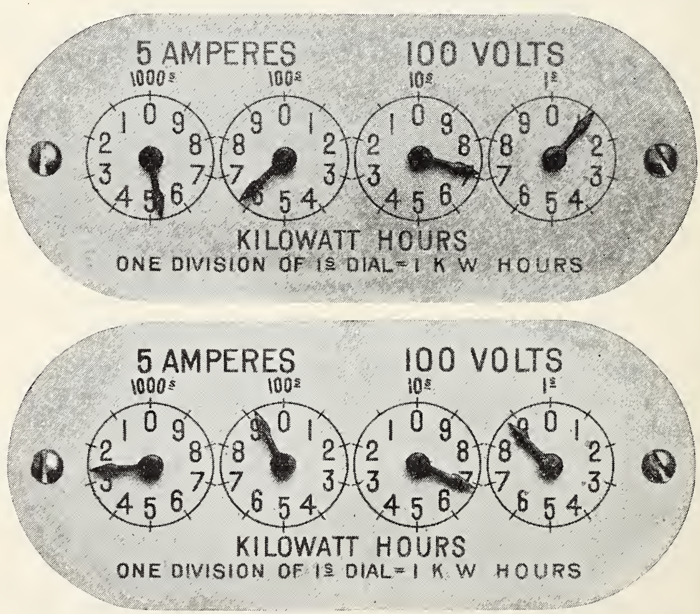
$$or\ \text{ohms} = \frac{\text{volts}}{\text{amperes}}$$

If you are studying mathematics, you recognize these three ways of expressing the formula as stating identical relationships. It is best to memorize the formula as it is stated first.

The units are difficult to define. The ohm is the resistance of a certain sized thread of mercury in a tube about a meter long. The ampere is the rate of flow of current that deposits a certain amount of silver from solution in a given amount of time. The volt is the pressure that keeps one ampere flowing through a resistance of an ohm.

How do we measure electrical power? No device will turn out more work than is put into it. In fact, when a dynamo supplies current to a motor, the motor will do less work than is required to turn the dynamo. Some of the electrical energy is lost as heat.

The rate at which a machine will do work determines its *power*. A pump which will pump 100 gallons of water a minute requires more power than does one which will pump only 20 gallons



The reading at the top is 5671 kilowatt hours. What is the reading of the meter below?

per mintue under similar conditions. If the pumps are operated by electric motors, the larger pump requires more electrical power to operate it.

The power of a current is measured in watts. A watt is one ampere of current at a pressure of one volt. The mathematical formula is watts = volts $\times$ amperes.

A 1-horsepower motor uses 746 watts of electricity if it is operating without loss of current as heat. Most washing machine and vacuum cleaner motors are $\frac{1}{4}$-horsepower motors. Such motors use $186\frac{1}{2}$ watts for power and actually about 200 watts altogether. The number of watts used is usually marked on lamps and irons. The number of watts marked on a lamp refers to the current flowing when the lamp filament is hot.

How is measurement of electricity useful? Use of electricity depends upon making devices to use it in the right amounts. If we have a 100-watt lamp on a 110-volt circuit, we can determine the number of amperes used thus: Since watts = volts $\times$ amperes, $100 = 110 \times$ amperes, or .909 amperes.

We may next find the resistance of the lamp from Ohm's law.

Since $\text{ohms} = \frac{\text{volts}}{\text{amperes}}$, we solve the problem thus: $\text{ohms} = \frac{110}{.909}$ or 121 ohms. The resistance of the lamp, when it is using 100 watts of current, is 121 ohms. However, the resistance of a hot filament may be as much as 14 times as much as that of a cold filament, and as a result a 100-watt lamp does not always use 100 watts of current.

What does the electric meter measure? We now know how the rate of flow of current is determined for the various devices. Each uses a current determined by its resistance.

When we pay the light bill, we buy a certain amount of energy, as measured by the meter. The meter reading is in terms of kilowatt hours. A kilowatt hour is one thousand watts of electricity flowing for one hour. That is, you may use ten 100-watt lamps or twenty 50-watt lamps for one hour, and the energy used will be recorded on the meter as one kilowatt hour.

The meter contains a motor which turns the hands on the dials of the meter. The first dial at the left indicates 10,000 kilowatt hours, the second dial 1000, the third dial 100, and the fourth dial 10 kilowatt hours. Units are read on the last dial. The highest reading the kilowatt hour meter can give is 9999 kilowatt hours.

You will note that the figures on the first and third dials run opposite the direction of the clock figures, while those of the second and fourth dials run in the same direction as do the figures of a clock. It is easy to read these dials, however, for you need remember only that each hand moves from the smaller to the larger number. You read the

Northwest Bell Telephone Company

A telephone cable contains many pairs of wires, one pair for each circuit. When a cable is spliced, each wire must be joined separately.

smaller number when the hand is between two numbers.

The meter reader carries with him a book in which he writes down your meter reading each month. By subtracting the reading of last month from the reading for this month, the number of kilowatt hours you use is determined. The number of kilowatt hours is multiplied by the cost per kilowatt hour. Current cost may vary from 1 to 10 cents per kilowatt hour.

The cost of current is determined by many things. The source of power—whether steam, Diesel engine, or water—is one factor. The average length of power line per customer, the amount of power each customer uses, the amount of service demanded by customers, and the business success of the company are other factors.

DEMONSTRATION: HOW IS ELECTRICITY MEASURED?

What to use: Two dry cells, iron and copper wire, pocket voltammeter (battery tester), file, ruler.

What to do: Measure the voltage

of the dry cells. Measure the current in amperes. The resistance of the materials inside the cell and the resistance of the tester determine the reading in amperes.

Attach an iron wire to one of the binding posts of a cell. Clean the wire with the file to insure good contact. Measure the current one foot from the binding post. Repeat with two cells in series and with copper wire.

What was observed: Make a table of the measurements you obtain. Calculate the resistance of the wire. Do not forget to subtract the resistance of the tester and cells.

What was learned: How does the resistance of various wires differ? How is a current measured?

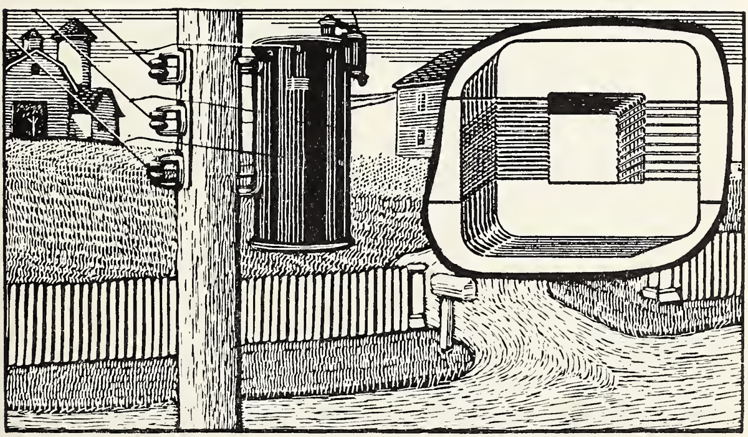
Exercise

Complete these sentences:

Resistance is measured in —1—, the flow of current in —2—, and the electromotive force or pressure in —3—. Ohm's law is —4—. The amount of power in currents is measured in —5—. Watts equal —6—. The unit of measuring current for paying the light bill is —7—. Three 50-watt lamps burning three hours a day for 30 days use —8— kilowatt hours of current. At five cents a kilowatt hour, this current would cost —9—.

7. How are currents controlled for use?

You have seen high voltage currents shoot sparks through space. You have seen wires become hot. You know that motors will burn off their insulation if too much current flows to their coils. You see the huge insulators on high-power lines, and yet you use current from these same lines in your house.



General Electric Company

The transformer which controls the current for house use consists essentially of two coils of wire and a magnetic core or ring (*inset*).

What is a transformer? Our light and power currents are controlled by transformers. A transformer is a device which changes the number of volts and amperes of an alternating current. It consists of two coils of wire wrapped around an iron core, as shown in the diagram. If the current enters through the side having the fewer coils, the transformer steps up the voltage, while if the current enters through the side having the greater number of coils, it steps down the voltage.

Its operation is simple. When electrons in an alternating current pick up speed, they send out a moving magnetic field. When they slow down, the magnetic field moves back to the wire carrying the electrons. When the electrons move in the second direction, the same thing happens except that the magnetic field is reversed. Thus a coil carrying an alternating current sends out a magnetic field every time the direction or voltage of the current changes. This magnetism is collected by the iron core, which in turn sends out a magnetic field. The coil through which current enters a transformer is called the primary coil.

In the secondary coil the magnetic field from the coil and iron core cuts through the conducting wires, and a current is produced. The voltage of the currents is in proportion to the number of turns of wire on the coils.

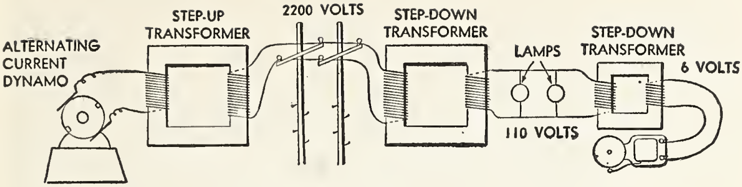
A transformer increases or decreases both the voltage and the current. If the voltage is increased, the number of amperes is decreased. If voltage is decreased, the number of amperes is increased. The amount of power in watts is unchanged except for the small amount lost as heat in the windings and iron core.

The uses of transformers are many. The current that is generated at the powerhouse may be distributed to a point 10 or 15 miles away. To avoid heat losses, the voltage is kept high, 11,000 volts being a rather common voltage for this distance. It is impossible to use a current of this voltage in the house. There are substations where the voltage is reduced, perhaps to 2200 volts. From the substation the current is carried into a transformer near the house where it is to be used and reduced to 110 volts.

To ring a doorbell or to run an electric train, the current is further reduced to about 6 volts. To prevent having too much current flowing through a transformer, the coils are so arranged that they resist the flow of current through the primary, letting only as much through as is needed.

Transformers are used to reduce the voltage of currents for welding and to brighten or dim lights in theaters.

What is an induction coil? When it is desired to change a direct current to an alternating current of different voltage, an induction coil is used. It consists of two coils and a core, just as a transformer does. But since a di-



This diagram represents the essential devices and changes in the current between the dynamo and your house.

rect current does not turn itself on and off, some device must be added to do this. In the ordinary induction coil there is a curcuit breaker just like the one on the doorbell which turns the current on and off. Some devices use a change in resistance to change the strength of the current.

When a current is turned on, or when its strength is changed, the strength of the magnetic field changes and the magnetic field moves. This moving magnetic field cuts the secondary coil and produces a current. Just as in the transformer the voltage depends upon the number of turns of wire in the two coils.

Induction coils are used in automobiles to supply the spark. They are also used in telephones, and they are sometimes used to operate lamps.

What are rectifiers? To change an alternating current to a direct current, devices called rectifiers [rĕk′tĭ·fī′ẽr] are used. There are a number of different types of rectifiers, working on rather different principles. Rectifiers are used in charging batteries and in radios.

How does resistance change current strength? A rheostat [rē′ō·stăt] is made up of a piece of high-resistance wire and some kind of slide which moves along the wire. Current flows through the wire to the slide. The longer the wire in the rheostat, the greater is its resistance. When the entire wire is in the circuit, the amount of resistance is high and the current is reduced. Usually the resistance wire is wound in a coil to save space.

Rheostats are convenient to use with small motors in shops to regulate their speed. Rheostats are used in arc furnaces and lamps to prevent a short circuit when the carbon rods are brought into contact. The wire in a rheostat frequently gets very hot, for when current flows through it, the energy encounters resistance. Rheostats which get hot must be cooled or protected to avoid fire.

DEMONSTRATION: HOW IS VOLTAGE CHANGED?

What to use: Induction coil, two dry cells, wires, screw driver, small motor, iron wire.

What to do: Connect the cells in series. Attach the binding posts of the primary coil to the dry cells. Make a contact across the posts of the second-

ary coil, and observe the spark. Hold a piece of paper in the spark.

Connect one post of the motor to the dry cells. To the other attach the iron wire. Slide a wire from the dry cell along the iron wire and observe the change in the rate of the motor.

What was observed: State what you observed.

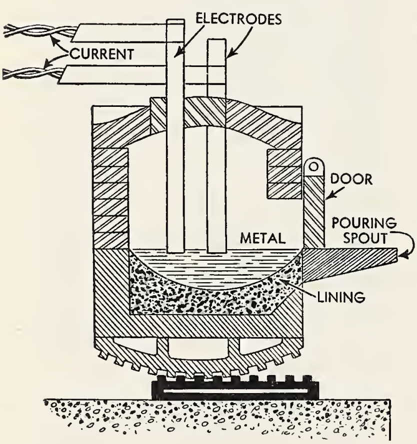
What was learned: Name two devices which change the strength of a current, and state on what principle they operate.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: INDUCTION COIL, TRANSFORMER, RECTIFIER, RHEOSTAT. *In the correct column write the following words (names of some devices may be written in two columns)*: telephone, battery charger, doorbell, spark plugs, toy train, neon lamp, welding, stage lights, substation, battery controlled motor.

8. How is electricity used for heating?

Why does the wire in the toaster get hot when the wire in the cord does not? Why does the wire in the electric lamp get hotter and give off less heat than the wire in the toaster?



In this electric-arc furnace resistance is provided by the materials placed in the furnace. The furnace is made of firebrick and other materials which resist heat. Equipment is provided for tipping the furnace to pour out the melted metals. (See page 75 also.)

What causes heat in a circuit? Heat is produced whenever a current encounters resistance. All conductors have resistance, and therefore give off some heat. The heat comes from the current and not from the resistance. The energy which is changed to heat is electrical energy, and the amount of heat produced depends upon the amount of current.

Many pupils have the incorrect idea that the more resistance there is in a circuit, the greater is the amount of heat produced. The opposite is true. Since more resistance permits less current to flow, more resistance produces less heat in a given circuit.

However, in a given circuit, when a heating device such as a toaster receives its current through copper wires, the most heat in this circuit will be given off where the resistance is highest. That is, the heating coil of the toaster has greater resistance than the wire in the cord and gets hotter.

In a given circuit the amount


Eugene Rosing

Electric welding is used in many types of repair work. The shield is used to protect the eyes from the intense ultraviolet light of the arc.

of heat given off is in proportion to the resistance, but in two different circuits of equal voltage the one having the less resistance will produce more heat. A 100-watt lamp has greater resistance than a toaster and gives off much less heat.

All circuits waste energy. Energy not used for useful work or heating is lost. Every wire is heated to some extent, and the heat is wasted. Energy is lost through poor insulators and short circuits. By using high voltages, large wires, and careful placement of power plants, power loss may be reduced.

How does the electric light work? The Mazda lamp is really a heating device. Less than 10 per cent of its energy is radiated as light, and the rest is lost in heat. Light is produced because the filament is heated to *incandescence*. The fine filament of wolfram (formerly called tungsten) wire offers high resistance to the current, permitting a small current to flow. The wire becomes very hot because of its small size. Filaments in gas-filled lamps are coiled in such a way that each turn of the coil keeps those next to it warm. The vacuum in small lamps reduces heat loss. In a vacuum, however, filament vaporizes rapidly and blackens the bulb. Lamps of less than 50 watts contain vacuums, and those larger than 60 watts usually contain nitrogen or argon gas.

How do heating devices work? The electric iron, next to the

electric light, is the commonest electrical heating device. The electric iron is made up of a coil of nichrome wire. Nichrome withstands high temperatures and resists oxidation well. This coil of wire is placed within the iron, between the upper and lower parts. The coil is insulated from the iron with mica and asbestos.

The temperature of the iron is controlled by a thermostat which turns off the current when the iron becomes hot. A thermostat is a safety device of the greatest importance, for with it the iron is less likely to become overheated and start a fire. The temperature of the iron is kept below the kindling point of cloth. The cloth may char, but it will not ordinarily burn. Even so, it is important not to leave a connected iron unwatched.

All the common electrical cooking devices are made up of the same type of coils that are used in the iron. Since the coil of wire is exposed in the toaster, the heat is given off by radiation. The coils in the percolator and waffle iron are covered, and heat is carried by radiation and conduction to the food being cooked.

The electric stove is largely a framework which supports simple heating coils. There are two types of coils. The open type is less expensive but has the serious disadvantage of being exposed to food spilling and of being a possible source of fire or shock. The other type of heating unit has a coil enclosed in a metal tube, which protects the wire from liquids and oxidation and prevents shock and fire.

The electric stove is usually operated on a different circuit, providing current from three wires, which provides power from two 110-volt circuits. A current of 220 volts is advantageous for use with a stove. To keep the danger of shock at a minimum, the metal of the stove must be insulated from the electric wires.

Electricity is rarely used for house-heating, except in spring or fall or where current is inexpensive. The usual heater is a portable coil placed in a reflector. In some houses a heating coil is built into a wall reflector.

Most driers are combinations of heating coils and electric fans. Driers are used for the hair, for hands and face in public washrooms, for photographic prints and films, and for industrial processes.

What is an electric furnace? The electric furnace which is used to melt metals and to make carborundum produces the highest temperatures available to man. It consists of a box or furnace of fire-resistant brick. Two carbon rods project into the furnace. The rods come together, and a current flows through the rods where they touch. The relatively poor connection heats them until they vaporize. Then the rods are slowly moved apart, and the current is carried by the carbon vapor. Such a gap filled with heated gas is called an *arc*. The arc furnace melts practically

anything put into it. There is another type of furnace that uses the resistance of materials put into it to provide the resistance to cause heating.

How is electricity used in welding? One of the most important uses of electricity in industry is for welding metals together. One type of welding equipment employs an arc, and the materials to be welded are melted together by the hot gas. The more common method is to press the pieces of metal together and run the current through them from each side. The resistance is greatest at the point of contact, and the metals melt from the heat. The heat and pressure used to hold the metals together cause them to be permanently joined. Welding is used in making washing-machine tubs, automobile bodies, streamlined trains, airplanes, chicken-wire fencing, and pipes and culverts. In fact, welding is rapidly replacing rivets in most industries. A current of low voltage and high amperage is used in welding.

DEMONSTRATION: WHAT PART OF A CIRCUIT IS HOTTEST?

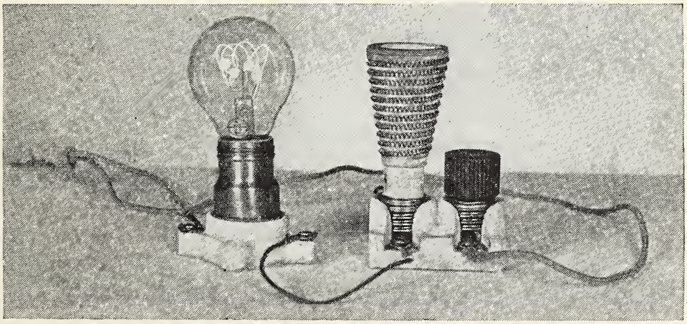
What to use: Lamp cord, light circuit, electric lamps, heating coil, sockets, dry cell, No. 30 copper and iron wire, carbon rods and supports, spring clothespin.

What to do: Connect the lamp and heating unit in series, as shown in the illustration below, on a regular 110-volt light circuit. Be sure the connection is in series. Turn on the current. Dry the hand, and place it cautiously on the heating coil. Is the coil hot?

Remove the lamp from the circuit, after turning off the current. Connect the heating coil in the circuit. (*Keep your hands off!*) Hold a piece of paper against the coil. Is the coil hot?

Hold across the binding posts of the dry cell a piece of copper and a piece of iron wire.

Make an arc. Support the carbon rods and connect them in series with the heating coil in the lighting circuit.



The heating coil does not become hot because the resistance of the lamp reduces the flow of current. The coil and lamp are connected in series. Why is the fuse used?

(*Be sure the connection is in series.*) Using a spring clothespin for insulation, move one of the carbon rods so that it touches the other, and slowly move it away. Observe the resulting arc.

What was observed: State briefly what you saw and felt.

What was learned: Why does the coil remain cool with the lamp in series? Why does it become hot without the lamp? Which is hotter, the lamp filament or the coil? Which is a better conductor, copper or iron? What offers resistance in an arc?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: nichrome, resistance, arc, coil, varies, current, iron, light, conductor, heat, length, size, series, parallel.

9. How is electricity used to do work?

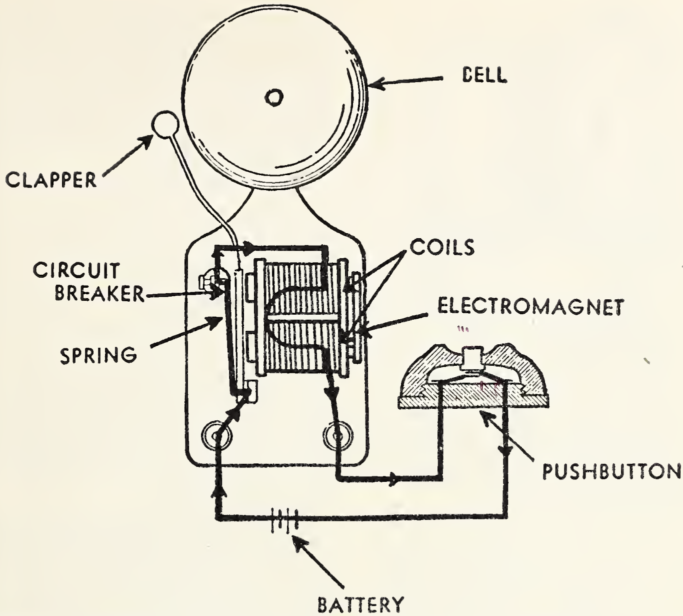
There are two common types of machines in which electrical energy is transformed into mechanical energy. One is the doorbell; the other is the electric motor. In both of these an electromagnet provides the energy to do the work.

How does the doorbell work? The essential parts of a doorbell are the circuit breaker, the electromagnet, and the spring armature. When the push button is pressed, it completes the circuit and causes the current to flow through the insulated coils and to the screw or point of the circuit breaker. From the point of the circuit breaker, the current is carried through the spring and to the frame of the bell. Every time the circuit is closed, the coils become electromagnets which pull the clapper and break the circuit. The electromagnets then lose their power, and the spring pulls the clapper back, closing the circuit. The clapper moves rapidly back and forth because the electromagnets and the spring pull upon it alternately. Any bar which is attracted by an electromagnet is called an armature.

Some electric razors and hair clippers work on the same principle as the doorbell. In these instruments the vibrating bar moves a comblike set of knives which cut or shave off the hair.

How does the electric motor work? The electric motor works upon the principle that like poles repel and unlike poles attract each other. If you put two permanent magnets in the position shown in the diagram on page 160, with the like poles of upper and lower magnets together, the pivoted magnet tends to turn in the direction indicated by the arrows until the north pole is directly over the south pole of the other magnet. It is impossible to make a motor employing permanent magnets, because when they once reach the position in which unlike poles are close together, the pivoted magnet comes to a stop.

The poles of electromagnets may be changed by changing the direction of flow of current



The electric doorbell is one of the simplest machines using electricity to do work. The black line shows how the current would flow if the clapper were all the way back against the screw.

through the coils. If we substitute an electromagnet for the pivoted permanent magnet, we can make the magnet turn again by changing its poles. This, essentially, is the plan of an electric motor.

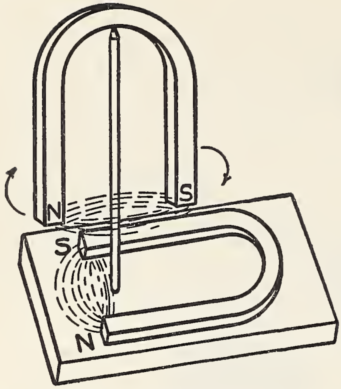
The parts of a motor are the same as those of a dynamo. The outer magnets are called the field magnets and produce the magnetic field which passes through the rotor or armature. The rotor is so made that it rotates between the poles of the field magnet. It consists of coils of wire wound upon soft iron cores.

Current is conducted into the coils of the rotor or armature through carbon brushes. In the case of the direct current motor, the brushes are in contact with the commutator. The alternating current motor has slip rings instead of a commutator.

The poles of the rotor and the field coils are wound and connected in such a way that like poles are always near each other, and unlike poles are not near each other. The like poles repel, and the unlike poles attract, causing the rotor to turn rapidly.

As the rotor turns, the poles are changed by the changing direction of current.

To do work, the energy of the spinning rotor must be conducted to some machine which uses mechanical energy. The rotor turns upon a shaft. Tools may



Like poles repel; unlike poles attract. Permanent magnets cannot be used in a motor because there is no way of changing their poles.

be connected directly to the shaft of the motor, or the power may be transferred to machines by use of gears or pulleys.

There are almost as many kinds of motors as there are jobs which can be done by electric motors.

The simple motor which is used for demonstration purposes in the laboratory has only two poles in the field magnet and two in the rotor or armature. Although this motor runs, it is not efficient. Because there is too much space between the poles of the field and armature magnets, magnetic force is lost. The two poles are not sufficient to supply an even flow of energy.

A commercial motor usually has a number of divisions in the armature or rotor and a number of coils in the field magnet. The diagram on the opposite page shows more nearly the appearance of a true electric motor. You will note that the field magnets are curved closely around the armature. The armature is divided into many parts.

What are some uses of electric motors? The electric motor has revolutionized housekeeping and industry. The motor used in the home is quiet, small, and strong. It can be moved from one place to another, for its only connection is the flexible insulated cord. It produces no smoke or poisonous gases. If it is properly constructed, there is little danger of fire from its use.

The electric motor runs the vacuum cleaner, the washing machine, the refrigerator, the sewing machine, the food mixer, the electric fan, the hairdrier, the clock, and many other common machines. The oil burner has a fan operated by electricity. Many stokers have motor-operated coal feeders and fans to provide draft. Practically all ventilation systems are driven by electric motors.

In industry the uses for motors are almost countless. The electric drill, saw, and planer are used in house construction. Lathes, band saws, and drills are used in machine shops. Buffers and polishers are almost always driven by electric motors. Factory sewing machines and laundry machines are motor driven. The electric motor is the most common source of power in industry.

Electric motors are used in many ways in transportation.

One type, operated by current from storage batteries, is used on warehouse platforms, in mines, and in light delivery trucks. Another type of motor is used on streetcars and electric trains which have overhead trolleys.

DEMONSTRATION: HOW DOES THE ELECTRIC MOTOR WORK?

What to use: St. Louis or other simple motor, two or three dry cells, wire, doorbell, 2.5-V flashlight lamp.

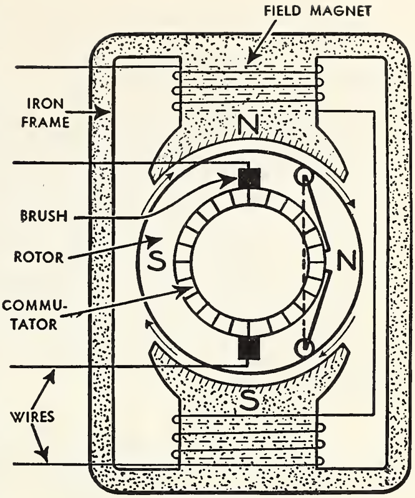
What to do: Set up the motor with the permanent magnets in place, one north and one south pole producing a magnetic field. Run current from the two cells in series through the binding posts of the rotor. Reverse the wires from the cells to the binding posts.

Remove the permanent magnets, and replace them with the electromagnet. Connect the rotor and field magnets in parallel.

Remove the wires. Connect the right-hand post of the armature with the left-hand post of the field magnets. Connect the remaining posts to the cells, producing a series connection.

Adjust the doorbell so that it rings slowly. Connect the doorbell and flashlight lamp in series to enough cells to ring the bell. The lamp will show that the current is turned on and off when the bell rings. Operate the system.

What was observed: Which method of operating the motor seems to produce best results? How does the doorbell work?



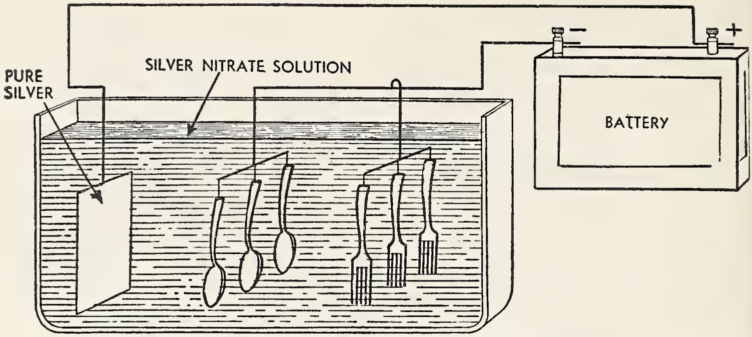
In this diagram an electric motor is shown. The rotor is made up of coils of wire. Each coil has its ends connected to a section of the commutator.

What was learned: State the principles which explain the operation of the electric motor and the doorbell.

Exercise

Complete these sentences:

The doorbell operates because the —1— attracts the armature and breaks the —2—. When the circuit is broken, the spring pulls the armature back into place, closing the —3—. The principle of the motor is that like poles —4—, and unlike poles —5—. There are two sets of poles: one on the —6— and the other on the —7—. Current is led into the armature through the —8—, which are in contact with the —9— of a direct current motor or the —10— of the alternating current motor.



This diagram shows how you could connect silver and articles to be plated in a plating solution.

10. How does electricity produce chemical changes?

By sending a current through conducting solutions or melted salts, the chemist today makes many needed materials. Cheap metals are coated with expensive metals, baby shoes are coated with bronze, and many necessary materials—aluminum, sodium, lye, chlorine, copper, magnesium, and hydrogen—are produced cheaply in pure form.

How is silverware plated? Your silver-plated spoons are really iron, except for a coating of silver thinner than a sheet of paper. The spoon is pressed from iron and shaped with the pattern stamped on the handle.

To plate the spoons, a solution of silver salt is prepared, and a bar of silver is placed in the solution. The spoons to be plated are suspended in the solution from a bar. The bar of silver and the spoons are connected by wires to the posts of a cell or dynamo. The silver is attached to the positive post, and the object to be plated is attached at the negative post.

The electric current causes the silver in the salt solution to be deposited on the iron spoon. The acid part of the salt combines with the silver of the bar, keeping the solution at a uniform strength. The silver bar is gradually reduced in size as silver is deposited on the spoons. The amount of silver deposited determines the value of the silverware. A single thin coating, called a wash, looks at first as good as any other quality of plating but wears off almost immediately. The best plated silverware lasts in ordinary use from 5 to 10 years, and it may last much longer.

How is copper purified? The method of purifying copper is very similar to the process of plating silver. When the copper ore is prepared by roasting and blowing air through the melted cop-

per in a converter, the copper formed is impure. A plate of pure copper is attached to the negative post of a battery or dynamo. The impure copper is connected to the positive post of the current source. Both pieces of metal are covered with a solution of copper sulphate. When the current flows, the impure copper goes into solution. Pure copper from the solution is deposited on the pure plate. The impurities settle to the bottom of the tank as "mud." This mud sometimes contains gold or silver.

How are book plates made? The plates from which this book was printed were formed by electroplating. The type, set by a linotype machine, and the pictures, made on metal blocks, were assembled in the form of pages. An impression was made by pressing waxlike material against the type. Copper was then plated over the impression in the wax plate, filling the hollow places left by the type with a thin plate of copper. Then the copper plate was removed, and type metal was poured into the letter forms to give them strength. The metal plates were set into the press, and the book was printed.

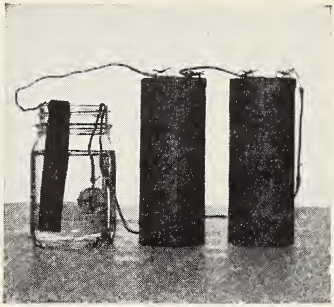
How is aluminum purified? The process of purifying aluminum is considerably different from that employed in purifying copper. Aluminum ore is dissolved in a mineral melted in an electric furnace. The aluminum ore dissolves in the liquid mineral and is separated into oxygen and aluminum by electrical means. The melted aluminum is drawn from the bottom of the tank, and more ore is added at the top. The electric furnace supplies heat to melt the materials, and also provides the current which separates aluminum from oxygen.

How are lye and chlorine made? Lye is a compound of sodium and water. Table salt is a compound of sodium and chlorine. To make lye and chlorine, it is necessary to separate the sodium from the chlorine in table salt.

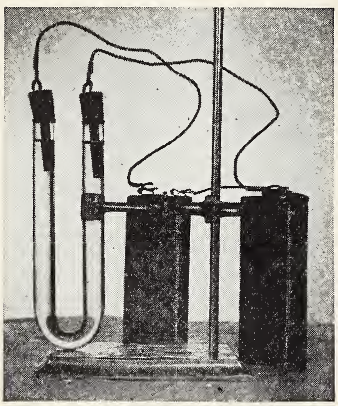
An electric current is run through a solution of table salt. The metal sodium is attracted to a negatively charged steel post in the solution. The sodium reacts with water, forming hydrogen and lye. The hydrogen gas passes off, and may be collected and put into tanks to be used for fuel for welding. The lye remains in the salt solution. When the solution is evaporated, the salt settles out first. Then the rest of the water is evaporated, leaving the lye behind. The lye is sold for making soap.

The chlorine is attracted to a positively charged carbon post in the salt solution. Chlorine is a greenish, bitter, poisonous gas. It is collected, dried, and pumped into tanks for use in purifying city water and for bleaching.

Why do currents break up chemical compounds? When acids, bases, or salts are put into water, they break up to a slight extent into charged molecules or atoms. The hydrogen molecules



The upper setup is being used to copperplate a foreign coin. The lower apparatus is used to separate table salt into other chemicals.



and the metallic atoms or molecules have positive charges. The acid-forming elements break up into atoms or groups of atoms having negative charges.

Now, as you know, *unlike charges attract.* The positive post of a piece of apparatus attracts negative charges, such as are held by oxygen and the chlorine. The negative post attracts metals and hydrogen molecules because they carry positive charges. Whenever a charged atom or molecule touches a charged post, it loses its charge and goes out of the solution. Gases rise to the top. Solids either are deposited or react with the water or go back into solution.

Solutions differ in their capacity to carry currents. Limewater and vinegar carry only small currents. Salt water and hydrochloric acid solutions carry current very well. Turpentine, alcohol, and oils do not carry currents.

The separation of chemicals in solution by use of electricity is called electrolysis. It is apparent that only direct currents may be used in chemical separation of compounds.

DEMONSTRATION: HOW DOES ELECTRICITY PRODUCE CHEMICAL CHANGES?

What to use: Sodium chloride, litmus cubes, U-shaped calcium chloride tube, one-hole stoppers to fit, carbon rods from flashlight battery, dry cells and wires, support, copper sulfate, copper and lead strips, beaker.

What to do: Dissolve a litmus cube in hot water. Into the water put a teaspoonful of salt. Pour the solution into the U tube, and support the tube so it will stand. Into each stopper put a carbon rod from a flashlight cell. Put the stoppers *loosely* into the U tube. Connect the carbon rods to two or more dry cells in series. Observe the color changes. Sniff cautiously at the side connected to the positive post.

Clean the lead strip or a foreign coin so that it is free from oil. Connect it to the negative post of two or more dry cells in series. To the positive post of the dry cell connect a clean copper strip. Prepare a saturated solution of copper sulfate—one-quarter pound

to a pint of water—either by soaking the crystals overnight or by heating them in water. Put the lead and copper strips into the solution.

What was observed: Report what was observed in each experiment.

What was learned: What types of chemical change may be produced by an electric current? Why did the litmus solution change color? Is chlorine a bleaching agent? How do you know?

Exercise

Complete these sentences:

Because metals have positive charges in solutions, they are attracted to the —1— post. Chlorine and oxygen have —2— charges in solutions, and are attracted to the —3— post. From a salt solution —4— passes to the positive post and —5— to the negative post. The iron spoon is connected to the —6— post for plating with silver. Aluminum ore is dissolved in a mineral melted by an —7—. —8— is used to purify water. Sodium in water forms —9—. Litmus is turned blue by chemicals called —10—.

A review of the chapter

Electricity is a form of energy. A current is a flow of negative charges, called electrons, along a conductor. Static electricity is stored in nonconductors.

A voltage is generated by cutting a magnetic field with a closed conductor or by chemical changes in cells. A magnetic field surrounds every conductor carrying a current.

The rate of flow of current is measured in amperes, the pressure in volts. Resistance is measured in ohms. Amperes equal volts divided by ohms. Power in watts equals volts times amperes.

When electricity encounters resistance, heat is produced. The heating effect of electricity is used in irons and lights. Like poles or charges repel each other; unlike poles or charges attract. Work is done in motors by so winding coils that like poles constantly repel and unlike poles attract each other when current flows through the coils. Electricity is used to produce chemical changes in purifying copper and plating spoons.

Many kinds of useful work can be done by devices which use electric power. Chemical action in cells and batteries produces electric current. Currents are controlled by such devices as transformers, induction coils, and rectifiers.

Word list for study

static	watt	rotor	induced
alternating	nichrome	magnet	ampere
thermocouple	transformer	parallel	storage cell
electromagnet	arc	kilowatt hour	commutator
cell	current	armature	fuse
volt	direct	induction coil	grounded
field magnet	compass	charge	incandescence
slip ring	galvanometer	photoelectric cell	brush
series	ohm	magnetic field	rectifier

An exercise in thinking

Write the numbers from 1 to 36 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. An electric current is a flow of electrons along a conductor.

B. An electric current may be produced by chemical action.

C. Every conductor carrying a current is surrounded by a magnetic field.

D. When a conductor cuts a magnetic field a voltage is generated which may cause a current to flow.

E. All materials resist the flow of electric current, which is changed to heat when resistance is overcome.

F. Amperes equal volts divided by ohms. $A = \frac{V}{O}$

G. Watts equal volts times amperes. $W = V \times A$

H. An electric current can produce chemical changes.

I. Like poles or charges repel each other.

J. Unlike poles or charges attract each other.

List of related ideas

1. A current of 2 amperes flows when a pressure of 6 volts encounters a resistance of 3 ohms.
2. Electricity is used for plating silverware.
3. Electrons move from the negative to the positive pole along a wire.
4. Voltages are generated in dry cells which contain sal ammoniac.
5. Two similarly charged pith balls don't touch each other.
6. Copper is deposited at the negative pole in a solution.
7. A current results when static electricity is discharged along a conductor.
8. When a heating coil and 40-watt lamp are in series, the lamp is hotter.
9. A transformer changes the voltage and amperage of currents.
10. A current is induced in the secondary coil of an induction coil.
11. An electric motor is made up of electromagnets.
12. With a wire, a nail, and a dry cell, one can make an electromagnet.
13. Storage batteries are charged by producing lead peroxide on one plate.
14. The compass needle points north.
15. A coil with an iron core is used to lift pig iron.
16. A lemon and zinc and copper strips, properly connected, produce a current.
17. Electric lights often have a resistance of more than 200 ohms when hot.
18. A 3-volt, 4-ampere current pro-

duces the same power as a 6-volt, 2-ampere current.
19. Book plates are formed by an electroplating process.
20. A dynamo consists of coils of wire turned between magnets.
21. Watches are magnetized if carried too close to coils carrying current.
22. Electrons, which are negative charges, are attracted to positively charged plates in the photoelectric cell.
23. Lye and chlorine can be made from table salt by using a direct current.
24. With a given voltage, increasing the resistance decreases the current.
25. Fuses melt when an overload of current flows through them.
26. A toaster works because of the heating effect of electricity.
27. One proof that a piece of iron is magnetized is to use it to repel another magnet.
28. The iron core of a transformer sends out a magnetic field to the secondary to produce a current.
29. Nichrome wire is sometimes used for heating coils.
30. Lightning sometimes sets trees on fire when it strikes them.
31. A magnet thrust through a coil causes the galvanometer needle to move.
32. Currents are produced when electrons are released by chemicals in solution.
33. A primary coil of a transformer magnetizes an iron core.
34. The rotor magnets and field magnets are wired so that like poles are caused to repel.
35. Country telephones are rung by a crank turning a coil between magnets.
36. The first currents were produced by stacks of copper and zinc strips, separated by cloths soaked in salt water.

Some things to explain

1. How was electricity used in printing this book?
2. In your house find five devices used to make electric wiring safe.
3. Why do gasoline trucks have a chain dragging on the ground?
4. If you had a bar magnet with the poles unmarked, how could you find which was the north pole?
5. Why is electricity more dangerous when you handle electrical devices with wet hands?
6. Write 10 rules for safety around electricity.

Some good books to read

Collins, A. F., *Fun with Electricity*
Compton's Pictured Encyclopedia
Lunt, J. R., *Everyday Electricity*
Meister, M., *Magnetism and Electricity*
Morgan, A. P., *Boy Electrician*
Morgan A. P., *Getting Acquainted with Electricity*
Morgan, A. P., *Things a Boy Can Do with Electrochemistry*
Neill, H. B., *Forty-Eight Million Horses*
Perry, J., *Electrical Industry*
World Book Encyclopedia
Yates, R. F., *Boys Book of Magnetism*

CHAPTER

4

Light and Its Uses

We depend upon our eyes to learn many of the things we must know in order to survive. We observe our surroundings to know what is going on. We read or look at pictures to learn about things not in our immediate environment. In order to see we must have three things—light, objects that will reflect light, and eyes that can see.

We help our eyes in many ways by controlling light. At night when the sun is gone we build fires or light lamps or use electricity to prolong the day. We use the microscope, the telescope, the spectroscope, and the camera to learn from the universe of great and small things the information we must know to advance our skill and knowledge.

We go to the movies to enjoy our leisure time, to dream of the life of adventure, and to escape our problems and difficulties for a short time. Taking and developing pictures is the most widespread of all hobbies.

Our health depends in many ways upon light. If we read by light that is too dim or by light that shines directly into our eyes, it may be necessary for us to obtain glasses to correct the damage caused by our carelessness. Our houses are too often not well arranged for good lighting conditions and, as a result, we must be very careful to obtain the best conditions possible whenever we read or study.

Some activities to do

1. Look through a hole in your hand. Roll paper to make a tube. Look through this tube with your right eye. Hold your left hand before your left eye. Move it back and forth till it seems to have a hole in it. Explain this optical illusion.

2. Make a pencil disappear. Put a pencil in a test tube, and lower the test tube into a beaker of water. Look at it first from the side, then from the top. Find the angle at which the pencil disappears.

3. The disappearing coin trick is performed by putting a small water

glass over the coin, which lies in the bottom of a bowl. When the bowl is filled with water and the glass with air, the coin will disappear.

4. Put a box containing a single pinhole over an unfrosted lamp bulb in a dark room. An image of the lamp filament will appear on the wall through the pinhole. Make a second pinhole and you will get two images.

5. Obtain a tall coffee can. Punch holes the size of a pencil all around the can, two inches apart and three inches from the bottom. Make a cardboard cover with two openings for the can. In one opening put an electric light, in the other a funnel. Put the can over the sink, turn on the light, pour water through the funnel. You will have a fountain of lighted water. Be sure the lamp cord and bulb are well insulated to avoid shock.

6. With a light meter measure the brightness of light at various parts of the room with no shades drawn. Draw the top half of the shades and repeat. Draw the bottom half only and repeat. If you have Venetian blinds, leave them first in the open position. Then lower them and measure the light with the slats at different angles.

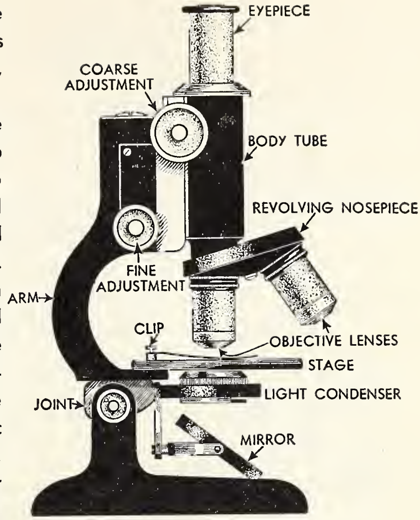
7. Organize a camera club. Projects you may work upon are construction and use of pinhole cameras, developing and printing of pictures, use of the ordinary camera, contests of snapshots, and making records of apparatus setups in the classroom. You should learn to take pictures indoors. Bring cameras to class and learn to use them.

8. Obtain shaving and convex rear-view mirrors, and study your image in each.

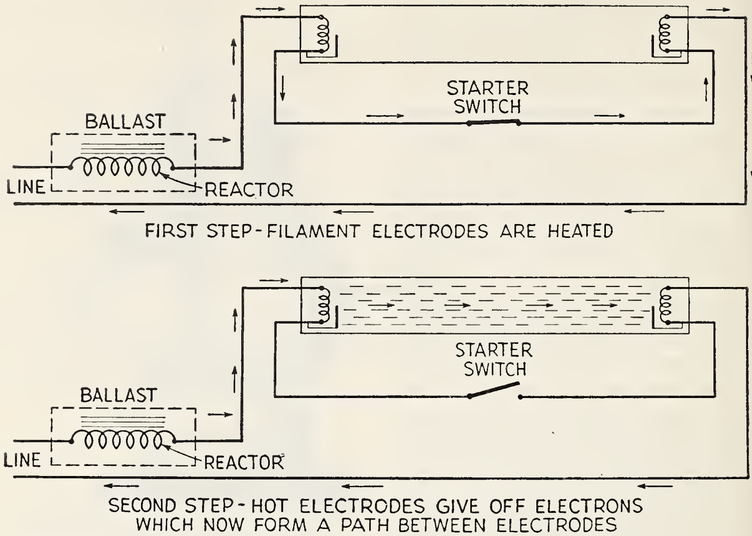
9. If you can afford a few dollars for materials and can spend most of your spare time for several weeks upon the work, make a reflecting telescope. Many boys have made such telescopes and have learned much about astronomy from their use. You can obtain much information from the *Scientific American* magazine to help you build your telescope.

10. Obtain colored cellophane, and view various colored objects through it. Make a chart of your results.

11. Put a colored cellophane cover over an electric lamp, being careful that it does not come into contact with the hot bulb and start burning. Try to identify the color of objects in the



By comparing this drawing with your classroom microscope, you can learn the correct names of the various parts. Remove the eyepiece from the classroom microscope. Can it be used as a magnifier? What kind of lenses must it contain?



Westinghouse Electric Corporation

Study this diagram carefully to learn how the fluorescent lamp operates. Note the positions of the starting switch. The ballast is a special kind of transformer.

room. This experiment must be done at night.

12. Make a chart of optical illusions.

13. Make a small hole in a newspaper. Look through the hole toward a bright light, and try to read the print near the hole. This experiment shows you what is meant by glare.

14. Make a refraction exhibit, using pieces of glass, bottles of water, and lenses you can obtain from discarded articles. Explain what each part of your exhibit does.

15. Obtain the help of someone in the community who owns a camera, and make a motion picture of some interesting activity at school. Follow directions given in the text.

16. Arrange a darkroom at home following suggestions in the reference books.

17. Make arrangements with an amateur photographer in your community to demonstrate for an interested group of pupils how enlargements are made.

18. Make an enlarger, following directions found in the reference book listed at the end of the unit.

19. Arrange to demonstrate before the class the construction and use of one of the projectors studied in this problem.

Some subjects for reports

1. Good and poor classroom illumination
2. Use of color for safety in home, school, and factory
3. Advantages of direct, semi-direct, and indirect lighting
4. The best kind of camera to buy

5. How professionally made movies are lighted
6. Color films, their use and development
7. Improving lighting in the home at small expense
8. Eyeglasses, types and fitting
9. Uses of special kinds of lamps

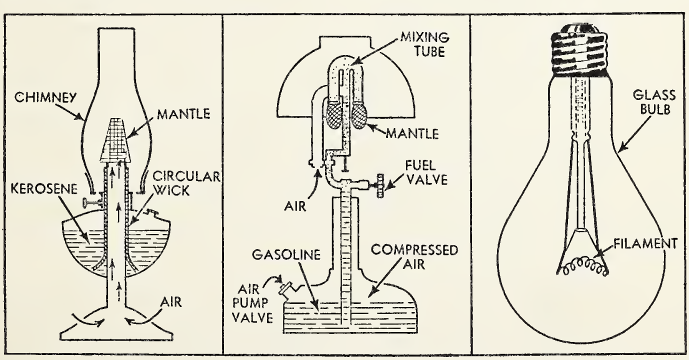
1. *How do we produce artificial light?*

One of the first advantages man gained over the wild animals was his mastery of fire and control of light. Because man learned to use fire, and found that the light it gave lengthened his day, he changed many of his habits of living. Today a day is actually 24 hours long and not merely the time from sunrise to sunset.

What are different types of lamps? The first lamp probably was a wick floating in a crude bowl of oil. The invention of the candle made it possible to carry the light more safely and store the fuel more readily than was possible with an oil lamp.

The first real improvement in lamps came with the use of kerosene as a fuel and the invention of the flat-wick kerosene lamp with a chimney to protect the flame. More recently the wick was made round, and air was admitted from a pipe through the center of the lamp. This arrangement produced a blue flame, which was used to heat a mantle. A mantle heated to incandescence [ĭn′kăn·dĕs′ĕns—hot enough to give off light], produces a clear light at low cost.

In the gasoline lamp the gasoline is forced by compressed air from the fuel tank through a carburetor, where it is mixed with air and blown into a burner which works almost like a blowtorch. The hot flame heats a mantle which gives off light. Gasoline lamps and lanterns are extensively used on farms, in camps,



Each of these pieces of lighting equipment depends upon incandescence to produce light. What produces the heat in each case?

and for outdoor life. The gasoline mantle lamp is equal in amount and quality of light to many electric lights. It is not as safe or convenient.

Near fields of natural gas, gas is still used to heat mantles to produce light. Gas lights are fairly efficient but are dangerous because of the poisonous nature of all illuminating gases. They also present a fire hazard, just as kerosene and gasoline lamps do. The use of gas for light was once common in almost all large cities.

What is the incandescent electric light? Edison invented the first successful electric light in 1879. It consisted of a carbon filament inside a globe from which the air was pumped. This lamp, with minor improvements in the filament, was used for several years. Then it was found that the metallic element wolfram or tungsten, on account of its high melting point and its resistance to oxidation, was suitable for filaments. Later the vacuum was replaced in larger bulbs with nitrogen, argon, or other inert gases. These gases improved the efficiency of the lamp by reducing the speed of evaporation of the filament.

All incandescent electric lamps depend for illumination upon heating a wire of high resistance by the current flowing through it. The larger lamps use more current and give off more light than do the smaller lamps.

The incandescent lamp of today is about 20 times more efficient than the first commercial lamp, put on the market by Edison, and now provides the best all-around illumination available at a moderate cost. One should buy an inside-frosted, gas-filled, wolfram or tungsten filament lamp, manufactured by a firm of good reputation. Only white lights should be used for illumination because colored lights are inefficient and tiring to the eyes.

Lamps should be used only on the voltage for which they are made. A 110-volt bulb on a 120-volt circuit gives bright light but burns out in about half the time that it should last. In general, it has been found that the larger lamp bulbs are more efficient than the smaller ones.

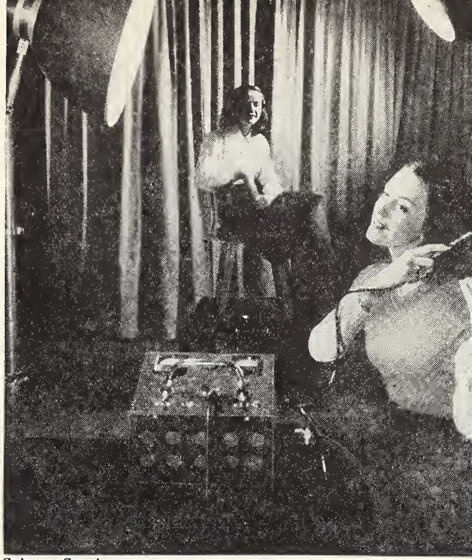
How do tube-type lamps work? A common gas-filled, tube-type lamp made without a filament is the neon lamp. Wires lead into each end of the tube. The current is discharged through the gas which is sealed into the tube under very low pressure. Molecules of the gas give off light when hit by electrons. Most tube-type lamps are operated from transformers which increase the voltage of the current. Neon lamps are used in signs and for decoration. Neon gas gives an orange color, mercury vapor produces blue, and helium a pale yellow-white light. By coloring the glass tubes, other colors are obtained.

The fluorescent lamp is the greatest improvement in lighting since the invention of Edison's lamp. It is a glass tube coated inside with a fluorescent mineral

and filled with gas under low pressure. These lamps are somewhat more than an inch in diameter, and range in length from 14 to 48 inches. The tube contains mercury vapor or krypton which is caused to glow by the current. Invisible ultraviolet energy is given off by the glowing gas. The ultraviolet energy is absorbed in a fluorescent paint on the inside of the tube. The energy of ultraviolet light is then given off, but at an increased wave length, and visible light is produced. Different chemicals inside the tubes produce different colors: green, yellow, blue, red, pink, daylight, or white.

Fluorescent lamps produce a soft, fairly even light. The daylight color is especially pleasing to the eye. A 15-watt fluorescent lamp gives as much light as a 40-watt Mazda lamp. These lamps require different circuits than do ordinary Mazdas and are somewhat expensive to install for home use.

One fluorescent lamp tends to flicker in use. Each time the alternating current comes on, the lamp lights. Thus the light turns on and off 120 times a second. By putting two lamps in a fixture, wired so that one is on when the other is off, the lights are turned on 240 times a second. This higher rate reduces apparent flicker. Transformers used with fluorescent lamps may send out magnetic fields which cause static on the radio.

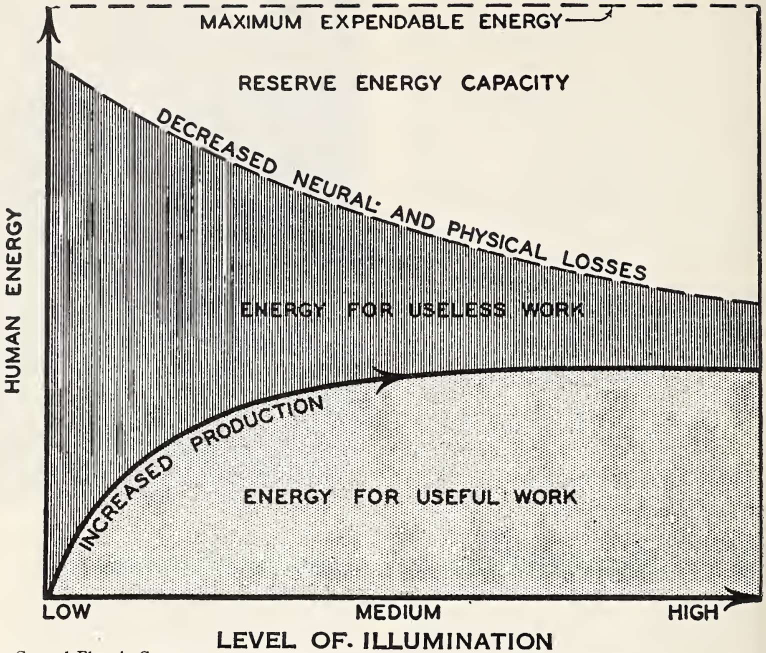


Science Service

Static electricity generated by the girl combing her hair was discharged through the two tube lamps, which provided enough light to take this picture.

What are the three photographic lamps? There are three types of photographic lamps. The photoflood is a Mazda lamp with a short, thick filament. It uses a large amount of current, and gives an intensely bright light. Photofloods burn out in two to ten hours. The photoflash is made of thin wires or sheets of aluminum or other metal enclosed in a bulb of oxygen. The current sets the metal on fire, and it burns with a brilliant flame lasting about one-fiftieth of a second.

A speed light used for photography discharges a spark through a gas-filled tube, making a single brilliant flash. The lamp unit contains an induction coil and may use either the light current



General Electric Company

As more light is used for doing close work the amount of energy wasted decreases and production increases. Thirty to fifty foot-candles are best for economy and good results indoors.

or a special battery. Taking pictures at speeds of 1/10,000 to 1/100,000 seconds is possible with this light.

How do radiant energy lamps work? Infrared lamps are used for treatment of certain diseases and muscular pains which are benefited by heat. They are essentially carbon-filament lamps, which are inefficient light producers and only moderately efficient heaters.

The ultraviolet lamp is used to treat some kinds of skin infections and to build up resistance to rickets in babies. Ultraviolet energy is used in restaurants to kill germs on glasses and dishes, which are usually put directly under the lamps. Such lamps are enclosed to protect the eyes of the restaurant workers who may be near.

DEMONSTRATION: HOW IS ARTIFICIAL LIGHT PRODUCED?

What to use: Various electric lamps, ultraviolet lamp, fluorescent minerals, induction coil, fluorescent Geisler tube, dry cells.

What to do: Set up various kinds of lamp bulbs side by side in the ordinary

circuit, and observe them to see if you can detect differences in their brightness. Compare old and new bulbs.

Send current through the fluorescent tube from the induction coil. Set up the ultraviolet lamp and the fluorescent minerals. Examine the minerals first under ordinary light, then under ultraviolet light.

What was observed: Report on each step of the experiment what you observed.

What was learned: What are two principles of producing artificial light?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: incandescent, carbon, nitrogen and argon, filament, resistance, tungsten, neon, mercury, fluorescent, photoflash, oxygen, ultraviolet, wave length.

2. How do we use artificial light?

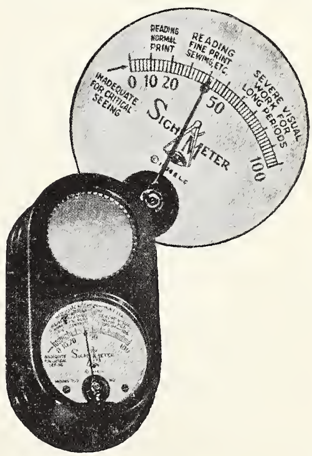
The correct use of artificial light is an important factor in health and efficiency. Modern ways of living make many demands upon our eyesight that primitive man did not encounter. Many common tasks require constant, close use of the eyes.

Good lighting must meet three major requirements. It must be bright to provide enough light for the work to be done. It must not glare. It must be steady and fairly uniform in different parts of the room.

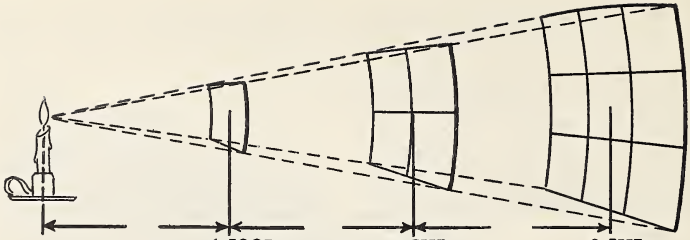
How may light be used safely? The standard unit of brightness of light is the foot-candle, which is the amount of light produced by a certain standard candle at a distance of one foot.

Practically, brightness of light is measured by use of a light meter, which consists of a photoelectric cell upon which the light falls and a galvanometer which measures the current from the cell. The brighter the light falling on the cell, the greater the amount of current produced. The dial is marked to be read in foot-candles.

The brightness of the sun at noon on a midsummer day may be as great as 10,000 foot-candles. The brightness of light in the shade on a summer day is about 1000 foot-candles. Bright moonlight has a brightness of only .02 foot-candle. The brightness of



The sight meter measures the brightness of light in foot-candles. The gray circle is part of a photoelectric cell.



The same amount of light that falls upon a surface at one foot from a candle covers a surface nine times as large at a distance of three feet.

light on a book three feet from a 60-watt Mazda lamp is 15 to 20 foot-candles. Brightness of light for reading should be more than 25 foot-candles. For general illumination and for housework, 5 foot-candles is sufficient.

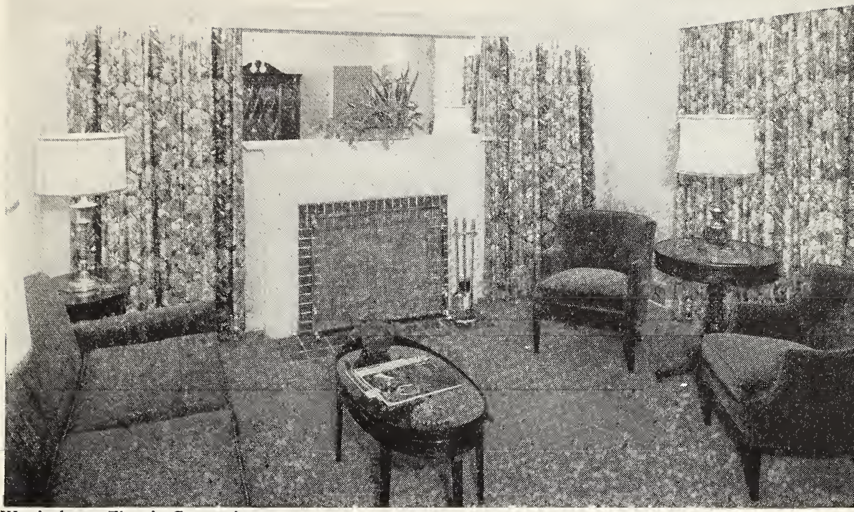
The brightness of light depends not only upon the source of the light but upon the distance from the light. If the brightness one foot from a candle is one foot-candle, the brightness two feet from it is only one-fourth foot-candle. The same light falling upon a surface three feet away is only one-ninth as bright as at a distance of one foot. The law is stated thus: The intensity of light varies inversely in proportion to the square of the distance from the source.

Glare results when any light shines directly into the eyes. The light may come from an uncovered lamp, or it may be reflected from a mirror or a varnished table top. When a glaring light shines into the eye, the pupil, or opening of the eye, closes up, and shuts out the dimmer, reflected light by which we see objects around us. The brighter the glaring light, the less we can see of ordinary objects. Glare is tiring to the eyes.

Good light is of uniform brightness. When we look at a part of the room which is very bright, the pupils of our eyes become smaller. If we then look into a part of the room that is dark, the pupils must become larger to enable us to see. Constant changing of the size of the pupil of the eye is tiring to the eye muscles and causes eyestrain. A flickering light is particularly tiring.

How can lamps best be used? Probably the poorest light in general use is the light from a kerosene oil lamp. It produces a light too dim for reading or sewing comfortably, even at a distance of a few inches. The light is glaring, and the room is hardly lighted at all by a kerosene lamp.

Gasoline and kerosene mantle lamps are usually provided with a shade of opal glass which scatters or diffuses the light to reduce glare. These lamps provide enough light for ordinary household needs. The usual practice of placing any lamp upon a low ta-



Westinghouse Electric Corporation

This living room is lighted by fluorescent lamps in a recess near the ceiling above the fireplace. The table lamps and tones of the walls and ceiling are excellent.

ble is not desirable, for the light should come from above instead of from directly in the line of vision.

The worst methods of using an electric lamp are to hang it from a cord in the center of the room or to put it in an exposed wall fixture. The old-fashioned bridge lamp, with its heavy, ornamental shade, its small lamp, and its small circle of bright light, is almost as bad.

At present there are two satisfactory types of floor lamps. One has a standard light socket into which the lamp screws base down. Around the lamp is a bowl of frosted or opal glass which diffuses the light. The lamp shade is white inside, and is made at such an angle that the light spreads over a fairly large area. A large part of the light shines on the ceiling to provide general illumination in the room, which makes the light more uniform.

The inexpensive student-size lamp requires a 100-watt standard bulb, and no other should be used in it. There is another lamp of this type with a three-way bulb; that is, the lamp contains two filaments, one using 100 and the other 200 watts. Either or both may be used at one time. This lamp with the three-way bulb is considered a poorer buy than the lamp using the standard bulb. Both the lamp and bulb are costly.

Two student lamps placed at

opposite ends of the room provide better light than does one three-way lamp, because the light is spread more uniformly. Floor and table lamps are far from satisfactory lighting devices. Their chief advantage is that one can get near enough to the source of light to obtain sufficient brightness for close work.

Another type of floor lamp has a circular fluorescent tube instead of a bulb inside the shade.

What is good illumination? There are two types of general illumination. *Direct* illumination comes either from bare bulbs or from bulbs in frosted diffusing bowls. Direct lighting lamps are sometimes placed in a recess in the ceiling. The light then shines through a pane of frosted glass downward into the room. Direct lighting is economical and, if properly used, is not injurious to the eyes. Much direct lighting is badly used.

In *indirect* lighting the light is reflected from the ceiling downward into the room. Light may be reflected downward into the room from lamps recessed behind a molding around the wall near the ceiling. Upside-down metal shades are also used to reflect light to the ceiling. Indirect lighting provides pleasing general illumination but is expensive and inefficient.

Many lighting fixtures on the market combine direct and indirect lighting.

Good wall and ceiling color improves illumination. Ceilings should be white because white reflects about 80 per cent of light. Walls should be light in color but not white because of the danger of glare. Most colors reflect less than half of the light falling upon them. Unusual interior decorating plans which use red, blue, green, or any dark ceiling and upper wall color should not be used in living or work rooms.

Bad lighting produces eyestrain, nervousness, muscle tenseness, fatigue, headache, and indigestion. Accidents occur more often when people work by dim light, work is slowed up, and the number of errors increases when insufficient light is used.

Proper lighting increases efficiency in doing work and may improve the health of those suffering from eyestrain.

For general illumination 100- to 300-watt bulbs in proper fixtures are best. Desk lamps, the lamps over the stove and sink, and bathroom lamps should be provided with at least 60-watt bulbs. Stair halls should have 60-watt bulbs.

DEMONSTRATION: HOW IS LIGHT USED?

What to use: Projector or box and lamps, frosted glass, light meter (may be borrowed from light company), simple optical bench and accessories, 5 candles, oil, paper.

What to do: Throw on the wall a beam of light from the projector or from a lamp inside a box in which a slit is cut. Put the piece of frosted glass in the beam of light, and note the change in its appearance.

Measure the illumination of the room with the lights on and off.

Measure the brightness of light one foot, two feet, and three feet from a single lamp in a darkened room.

Make a grease spot on a piece of paper. At one end of the optical bench put 4 candles, at the other end put 1 candle. Support the paper at the center of the bench with the grease spot in line with the candles. Move the lighted candles back and forth until the grease spot disappears.

Measure and compare the distances from the grease spot and candles.

What was observed: Record briefly your observations.

What was learned: How is light diffused? What factors affect brightness of light?

Exercise

Complete these sentences:

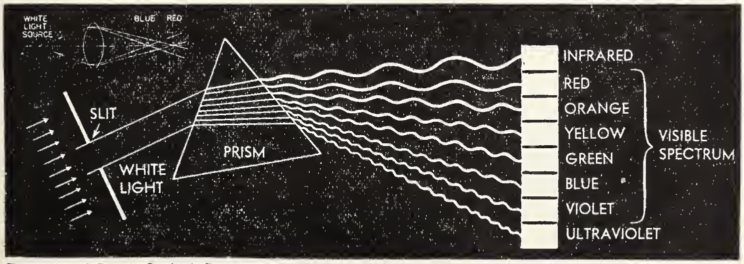
Candlelight is not —1— enough for adequate seeing. A glass-topped desk may cause eyestrain from —2—. Sunlight in a room produces a lack of —3—. A lamp producing 100 foot-candles at one foot distance gives a brightness of —4— foot-candles at five feet. The best color of light for easy seeing is —5—. The light meter is a device for measuring light by the amount of —6— it produces when shining upon a —7— cell. Light reflected from the ceiling is said to be —8—. A bare lamp gives the —9— type of lighting. The only satisfactory color for a ceiling is —10— for safe light for work areas.

3. *What is the nature of light?*

If you were asked which reflects more colors, a painting or a piece of white paper, you probably would select the painting. You would be wrong. Even the gaudiest painting absorbs more colors than it reflects. A piece of white paper does not absorb any color.

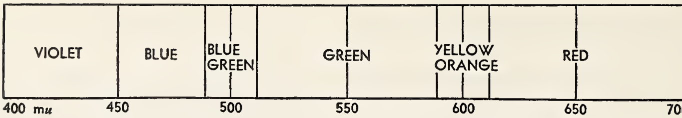
What is color? It is light that has color and not colored objects. In a completely dark room all objects are black—that is, without color. It is possible for objects to have color only as they reflect or separate light.

You have seen rainbows with their colors ranging through vio-



Bausch and Lomb Optical Company

White light may be separated into bands of color called the spectrum.



The color of light is determined by its wave length. This diagram shows the relation between color and wave length. The figures represent millimicrons, the units of measurement for light waves.

let, indigo, blue, green, yellow, orange, and red. The colors of a rainbow are called the spectrum. The raindrops separate the light that passes through them into the colors of which the light is made.

Our eyes are so constructed that they contain three kinds of nerves which are sensitive to three colors: red, green, and violet. Each kind of nerve is sensitive to some extent to other colors. Some eyes are not sensitive to any colors, but are color-blind. Most color blindness results from inability to distinguish between red and green.

When the colors to which the eye is sensitive strike it in equal amounts, the eye sees white. Some colors which the eye sees depend upon its ability to be deceived. If a variously colored wheel is rotated rapidly, the colors seem to blend. Red and blue blend to make purple. Blue and yellow blend to make green.

An object has color because it reflects only part of the light which falls upon it. For example, a red object absorbs all colors but red and reflects only red. A blue object absorbs all colors but blue.

Let us produce the spectrum on the wall of the science room by shining a beam of light through a glass prism. The prism bends light rays and separates the colors which make up white light. The light falls in colored bands. The violet light is bent most, the blue next, green next, and so on. Red is bent least.

Light is a form of radiant energy which travels in waves. Color really depends upon the wave length of light. The average distance between light waves is only 1/50,000 of an inch. There is a unit for measuring the wave length of light called the millimicron. Violet light waves are about 400 units in length. Light waves between 400 and 500 units in length look blue. Light with a wave length of between 500 and 600 units looks blue-green, green, or yellow-green. Light waves between 600 and 700 units in length are orange-red or red.

The waves just shorter than 400 units in length are called ultraviolet energy, while those just longer than 700 units in length are called infrared energy. Neither is visible. Both come from the sun, just as light does, and if our eyes were more sensitive we could see by these types of energy.

How do light waves travel? Light waves travel through space, apparently without being carried by any material. We know that water waves travel in water,

sound waves in air, and waves of rope along the rope. It has not been proved that light travels in anything. Light is one of the electromagnetic radiations.

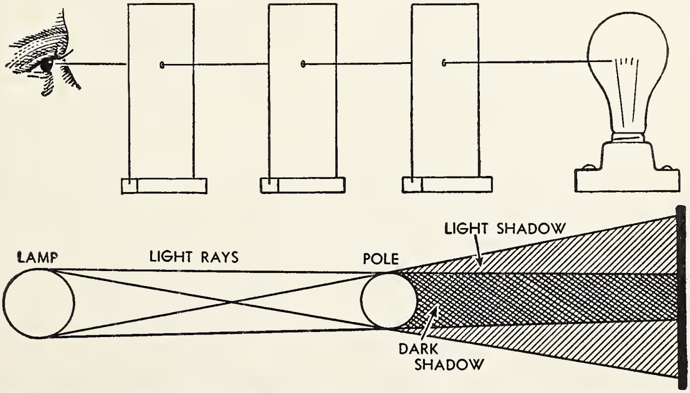
Light travels at a speed of more than 186,000 miles a second. That is, the light from the sun, which is 93,000,000 miles away, comes to us in about eight minutes. Light from the stars travels for years before it reaches us.

Light waves move in straight lines. If you put three cards in a row, with holes in them arranged in a straight line, a light can be made to shine through all three holes.

Because light travels in straight lines, shadows are formed where light is shut off by some opaque [ō·pāk′] object. If the light comes from a point or in parallel rays from the sun, the edges of the object are sharp and black. If the light comes from a broad surface, such as a kerosene lamp flame or a neon sign, the shadow is blurred. Directly behind the object there is a dark shadow which is called the *umbra*. The hazy, lighter shadow area in which the light is not entirely shut off is called the *penumbra*. Shadows are rarely completely black because dust in the air scatters light. Light may also be reflected from near-by objects into the shadow.

Does light pass through all substances? Materials vary greatly in their ability to transmit light. Opaque substances, such as wood, stone, metal, and leather, do not transmit a visible amount of light. Translucent materials transmit some light but diffuse it. One cannot see clearly through such translucent materials as paraffin and frosted glass. Transparent materials transmit enough light that we can see through them. Glass, water, air, and quartz crystals are transparent.

Some materials may be transparent and yet absorb much



Light travels in straight lines. It is possible to see the lamp only when the holes in the cards are in a straight line. The top view of the shadow of a pole as produced by a street lamp also shows that light rays travel in straight lines.

light. Red cellophane absorbs all the colors from light but red. If we look at a blue dress through red cellophane, the dress looks almost black. Ordinary window glass permits visible light to pass through but absorbs ultraviolet energy. Sunshine which enters through the window cannot sunburn us or help to develop resistance to rickets. One type of glass absorbs infrared rays—the heat rays—and helps to keep the house cool in summer.

Materials not only absorb light in different amounts and absorb different colors, but one material —Polaroid—also absorbs light waves that travel in certain directions. Light waves move from side to side or up and down as do waves in a rope. If you put the rope through a picket fence, you can shake it so that up-and-down waves go through the fence, but the sidewise waves are stopped by the pickets. Similarly, Polaroid stops all waves except those which lie in the direction of the crystals of which it is made.

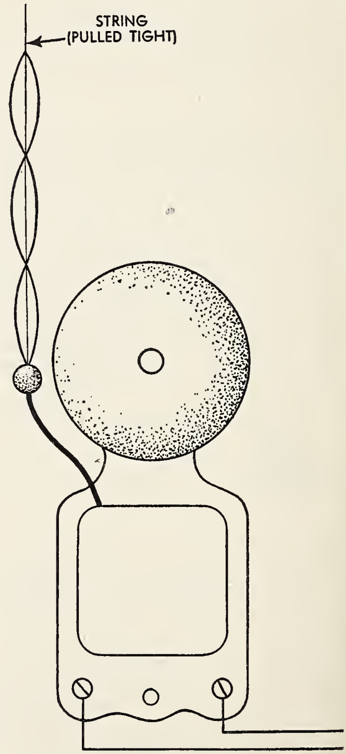
If you cross two pieces of Polaroid, they shut out almost all light. That is, if you put one piece of Polaroid over a headlight and another at right angles to it in a windshield, the headlight is seen as a dim glow instead of a brilliant glare through the windshield. Yet all objects illuminated by the headlight look perfectly normal because the diffused polarized light is remixed. Polaroid absorbs more than half the light that strikes it, and if it is used in headlights we need brighter than ordinary lights.

Polaroid is used to judge flaws in glass, to produce color effects, to study chemical composition of materials, to make better photographs, to make three-dimension movies, and to locate strains in models of machines.

DEMONSTRATION: WHAT IS THE NATURE OF LIGHT?

What to use: Doorbell, dry cell, string, prism, projector or sunlight, cardboard, Polaroid, if available.

What to do: Set up the bell appa-



This apparatus may be used to produce waves of various lengths. Changing the tension upon the string changes the length of the waves.

ratus as shown in the diagram. Bend the clapper so that it makes no sound, and complete the circuit. The length of the waves may be regulated by pulling on the string. Try to measure the wave length of the waves. See if you can stop the waves by putting the string through a slit in a piece of cardboard.

In a darkened room set up the prism in a beam of light, and turn it until a spectrum falls upon the wall or ceiling. Study the spectrum.

If Polaroid is available, follow the directions which come with the apparatus.

What was observed: Describe what was done.

What was learned: What is meant by wave length? What is the source of color? How does polarized light differ from ordinary light?

Exercise

Complete these sentences:

Light is a form of —1— energy which travels —2— miles a second. It moves in —3— lines with a —4— motion. Light passes freely through —5— substances; it is scattered but passes through —6— substances, and does not pass through —7— substances. Color of light depends upon its —8—. —9— energy, which causes sunburn, is invisible. All colors are reflected equally by —10— and absorbed by —11— objects. White light is separated into colors by a —12—.

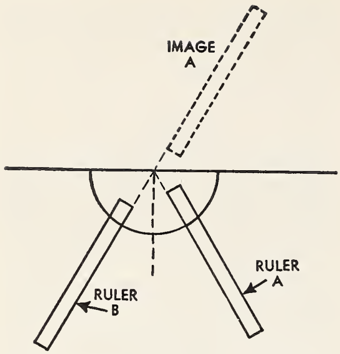
4. How is light reflected?

When you go to amusement parks you may see yourself in the crazy mirrors as you never look (you hope) in real life. Yet in your mirror at home, you look quite normal. Have you ever wondered why the curved mirrors make you look as they do?

How is light reflected? Light is reflected by surfaces through which it does not pass. The best reflecting surfaces are mirrors made of highly polished metal and ordinary silver plated mirrors. Certain white chemicals, such as magnesia, snow, and zinc oxide, reflect as much light as do mirrors, but scatter it so that we do not see reflections on their surfaces. All these objects reflect more than 80 per cent of the light falling upon them. Among the poorest reflectors are soot, black velvet, and black-tar paving material, all of which reflect less than 5 per cent of the light falling upon them.

Ordinarily glass reflects some light from both surfaces, whether it is silvered or not. This reduces the amount of light passing through windows, lenses, and windshields. In order to reduce undesired reflection, a layer of metal one molecule thick may be deposited on the glass. Such coated glass reflects much less light than does ordinary glass.

When light strikes a surface and is reflected, it leaves the reflecting surface at the same angle at which it strikes. To illustrate this, lay a ruler upon a table in front of a mirror, placing both upon a piece of paper. Stand the mirror up. Draw a line along the back edge of the mirror and along the edge of the ruler, and



You can test the law of mirrors with this apparatus.

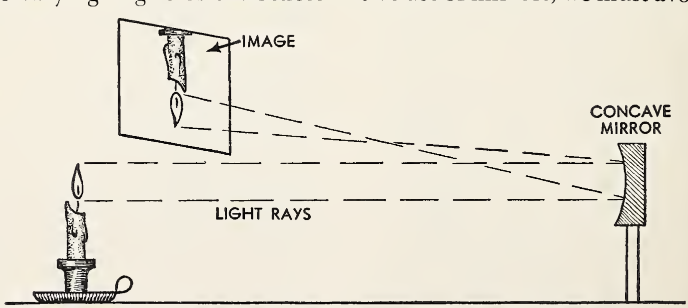
measure the angle at which the light strikes the mirror. Lay a second ruler upon the paper, lined up with the image of the first ruler in the mirror. When the second ruler and the image seem to be in a straight line, draw a line along the edge of the second ruler, and find its angle in relation to the mirror. The first angle, the angle of incidence [direction of approach], equals the angle of reflection. This observation is called the law of reflection.

When light strikes an uneven object, it is scattered because of the varying angles of the reflecting surfaces. Light is scattered or *diffused* by snow, dust in the air, and clouds. Diffusion of light causes dawn and twilight.

Where is the image in a mirror? You have noticed that your image in a mirror is reversed, that is, your right hand becomes the left hand of the person you see in the mirror. Print is backwards. Moreover, you see the image, not at the surface from which the light is reflected, but at a distance behind the mirror apparently equal to the distance from the mirror to the object reflected. If you are four feet from the mirror, you are eight feet from your image.

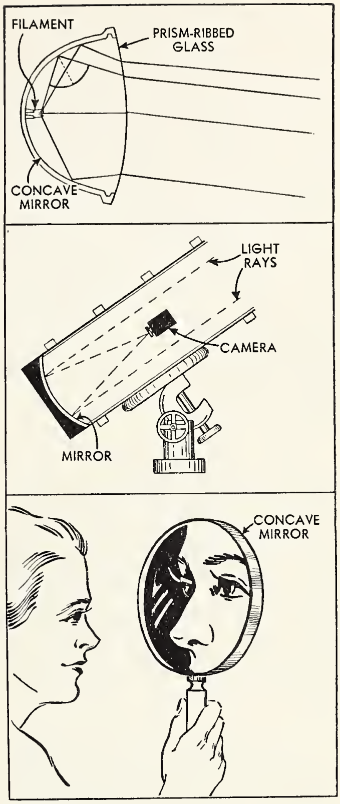
Actually, there is no image in a mirror at all, as a kitten learns when it runs around the mirror to find the second cat. An image that is not where it seems to be is called a *virtual* image.

Because the virtual image is apparently behind the mirror, the use of mirrors increases the apparent size of rooms and gives a feeling of spaciousness that many people desire. In decorative use of mirrors, we must avoid



A concave mirror projects an image upon a screen. To see the image clearly, the screen should be shaded. Note the position of the image.

reflecting light into the eyes of persons who must sit facing the mirror. Mirrors are common sources of glare.



Concave mirrors have three important uses: they serve as reflectors to concentrate beams of light; they are the essential parts of the largest telescopes; and they serve as magnifiers.

How are curved mirrors used? One of the most important means of controlling light is the concave mirror. The word *concave* means hollow and rounded. (To help your memory—a cave is hollow!) The inside of the bowl of a spoon is concave. A concave mirror brings light rays together. The extent to which rays are brought together depends upon the curvature of the mirror.

The automobile headlight reflector is a concave mirror. The lamp filament is put at the center of the curvature—that is, if a circle were drawn with the lamp at the center, part of the circle would lie along the surface of the reflector. The rays that shine out in all directions from the lamp are concentrated by the headlight reflector upon the road as a single beam of nearly parallel rays.

The concave mirror is used for a reflector in most searchlights. Motion picture projectors usually have a concave mirror behind the lamp, which almost doubles the amount of light available to illuminate the image upon the film.

The image produced by a concave mirror can be projected upon a surface. With a concave mirror, a lighted candle, and a card, you can project an image of the flame, as shown in the diagram. In order to make the image visible, the card must be shaded from the direct light of the candle. The image of the candle flame on the card is called a *real* image, for it has an exact location upon the surface of the card.

When light rays from a distant object are brought together at a point, they are *focused.* All the light rays from the tip of the candle flame which strike the mirror are brought back together, or fo-

cused, at a corresponding point on the card. All the rays from the bottom of the flame are focused at another point, producing an image of that part of the flame. The image of the flame is inverted and reversed by the concave mirror.

The concave mirror is used in the astronomical telescope. A star can be photographed by using the concave mirror to focus the dim light of the star on a photographic film. The largest concave mirror is used in the 200-inch telescope.

The concave mirror is also used as a magnifier, for the light it brings to the eye seems to come from an object larger than the actual object. Because of this, concave mirrors are useful in studying the skin for removing blemishes. Many shaving mirrors and dressing table mirrors are concave.

The convex mirror is exactly opposite in shape to the concave mirror. It is rounded outward like the outside of the bowl of a spoon. The convex mirror spreads light rays and makes objects look smaller than they really are. Convex mirrors are useful in powder compacts, for they enable a woman to see her entire face at one time. The convex mirror is also used as a rear-vision mirror, making it possible for the driver of a car to see all the road behind him on a reduced scale in the mirror.

The mirrors in the amusement parks are unevenly matched sections of cylinders—some parts of the mirror being concave and some convex. When one stands at the right distance, the concave mirror enlarges the image, and the convex mirror reduces it, so that the parts of the body are changed in proportion.

DEMONSTRATION: HOW DO WE USE MIRRORS?

What to use: Plane mirror, concave mirror, paper, rulers, pencil, protractor, candle, cardboard.

What to do: Measure the angles of incidence and reflection by the method described in this problem.

Project and study an image of a candle flame, following the information given in this problem. Use the concave mirror to study your image.

What was observed: Make simple sketches to illustrate your observations in each part of the demonstration.

What was learned: How do these demonstrations illustrate the law of mirrors?

Exercise

Complete these sentences:

Light rays are —1— when bent by a surface through which they do not pass. The angle of —2— equals the angle of —3—. A person five feet from a mirror is —4— feet from his image. —5— mirrors focus light rays at a point. —6— mirrors are used in reflectors and telescopes. —7— mirrors reduce the apparent size of the image. —8— mirrors are used for rear-view mirrors. Light reflected from irregular surfaces is said to be —9—.

5. How do the refractors bend light?

You have learned that reflected light is bent by surfaces through which the light does not pass. Light is also bent as it passes from one material to another of different density. This second type of light bending is called *refraction.*

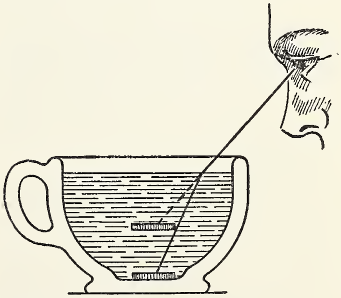
How does water refract light? If you put a pencil in a glass of water, the pencil seems to be broken at the surface of the water, and the part beneath the water seems to be curved and changed in size. As you turn the glass of water, the pencil seems to change shape.

Objects on a lake bottom seem to be nearer the surface than they actually are. Some Indians use spears to catch fish. The fisherman stands upon the bank with his spear poised so that he can throw it instantly at any fish he may see in the water. He aims, not at the point where the fish seems to be, but at a point considerably below the fish. It is necessary to make a correction for the refraction of light.

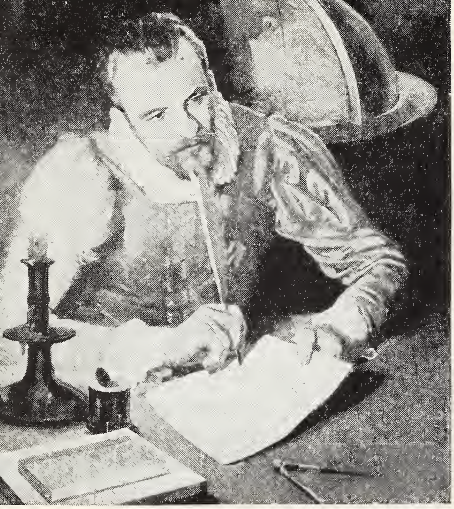
If you put a coin in the bottom of a cup so that you can barely see one edge of it and, without moving the eye, coin, or cup, pour water into the cup, the coin becomes visible. The refraction of light actually makes it possible to see around a corner.

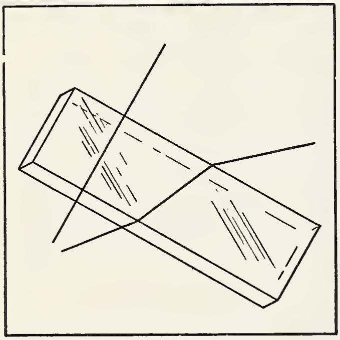
Does air refract light? The air is not equally dense at all places. Warm air is less dense than cold air, and upper air is less dense than air near the surface of the earth. There are various conditions under which light is refracted by air. One of these is the mirage. You have heard or read stories of weary, thirsty desert travelers seeing beautiful lakes which seem always to stay in the distance. The imaginary lakes are the result of refraction and reflection. There is a layer of hot air along the ground in which the sky is reflected. The reflected light is then bent, as it passes into the air, and again comes to the earth where it strikes the eye of the traveler. The blue color of the sky is mistaken for a lake.

Air is dense enough to refract light even at a height of about 100 or 200 miles. When sunlight approaches the earth at an angle less than a right angle, the light is bent earthward by the air. Light that would otherwise miss the earth entirely is thus refracted to make the day a bit longer in the morning and evening than it would otherwise be. We actually gain about 40 hours of daylight a



Do the experiment by sighting over the edge of the cup. As someone pours water into the cup, observe the coin.





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The law of refraction was discovered as the result of experiments performed with four pins and a piece of glass. The discoverer, Willebrord Snell, holds in his hand drawings showing the path of light through the glass. The drawing below shows how you can do the same experiment.

year because of refraction at sunrise and sunset.

Because light strikes the polar regions at a slanting angle, the total amount of extra sunlight there is about 65 hours more each year than is received at the equator.

Does glass refract light? You can measure for yourself the refraction of light passing through a piece of glass. Obtain a piece of cardboard and a small square piece of plate glass. Place the glass upon a paper on the cardboard. Thrust two pins into the cardboard. Then, beyond the piece of glass, thrust two more pins in line with the first two, as seen through the glass. Draw lines as shown in the diagram, and you will have a picture of the path of a beam of light through the glass.

The glass prism is used to separate white light into the colors of which it is composed. Because the eye is easily deceived by colors and cannot separate mixed colors, the prism is invaluable in finding the true color of light.

Each element, when it is hot enough to give off light in its gaseous state, produces a combination of colors which is produced by no other element. By passing the light through a prism and by measuring exactly all the lines of colored light which are produced, we can learn what element is being studied from the light it gives off. No one element gives off all colors. There are gaps in all spectra. Colored bands of light from an element are separated by black or unlighted bands. By throwing the spectrum upon a screen and carefully measuring the location of the bands of darkness and of color, we can identify any element. The device which is used for this work is called a *spectroscope.* It contains

one set of lenses for throwing a beam of light upon the prism, a screen built in with a scale measured upon it, and a magnifying glass or telescope for looking at the scale.

The eye is unable to distinguish blended colors. When you think you see a red light, it may really be a mixture of red, orange, and green. If a beam of red light is passed through a prism, the colors are separated and each can be seen. Matching colors is best done by use of the spectroscope.

Is refraction useful in controlling direction of light? The concave mirror is used to concentrate the beams of a headlamp. To pull the beam of light down on the road, a lens is placed in front of the lamp. This lens is made up of a series of ridges or flattened prisms. These prisms do not bend the light enough to separate it into colors, but turn the whole beam toward the road.

Prism or ribbed glass is used in windows to throw light into the room. Ordinarily, light falls upon the floor a short distance from the window. By putting prism glass in the window, the light may be thrown across the room. Prism glass must be used carefully because of the danger of glare from the rays of light thrown into the room. One should never work directly facing a window in which prism glass is used.

What is the best refractor? The white diamond is a crystal of carbon. Colored diamonds contain traces of other minerals. A diamond is beautiful because it refracts light much as a prism does, separating the white light into colors. The diamond is cut to give the greatest possible amount of refraction and reflection of light. A diamond bends refracted light about twice as much as does water. The amount of refraction produced by glass is only two-thirds that produced by a diamond.

Bausch and Lomb Optical Company

Joseph Fraunhofer, the inventor of the spectroscope, was the first to measure the dark lines in the spectrum of sunlight.

DEMONSTRATION: HOW IS LIGHT REFRACTED?

What to use: Projector or sunlight; red, yellow, blue, and green cellophane; cardboard; glue; prism; water glass; pencil; ribbed glass.

What to do: Prepare four filters as follows: Cut a hole about two inches in diameter in a piece of cardboard, and

over the hole attach cellophane with the glue. Shine sunlight or light from the projector upon the prism. Place the prism in such a position that a spectrum falls on a white wall or ceiling. In turn, place each of the four cellophane filters in front of the light beam, causing the colored light to fall on the prism. Observe the spectrum upon the wall carefully. Observe what colors actually pass through each filter.

Hold a piece of ribbed or prism glass in the projector beam.

Place a pencil in a glass of water, and observe the changes which you can produce in its appearance.

What was observed: Make a record of the colors which passed through each filter. Was the cellophane color actually pure or a combination of blended colors? What changes occurred in the appearance of the pencil?

What was learned: How is the prism used to study color? What is refraction?

Exercise

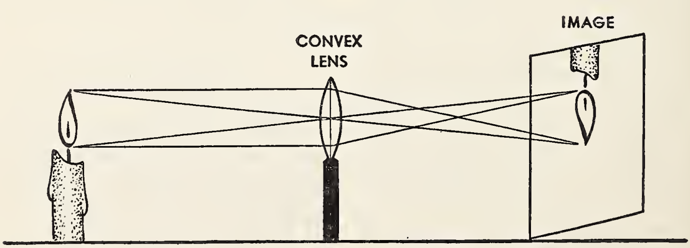
Write a paragraph summarizing this problem, using in the paragraph the following words: refraction, spectrum, water, glass, density, mirage, element, prism, bending, spectroscope, diamond.

6. Why do we use lenses?

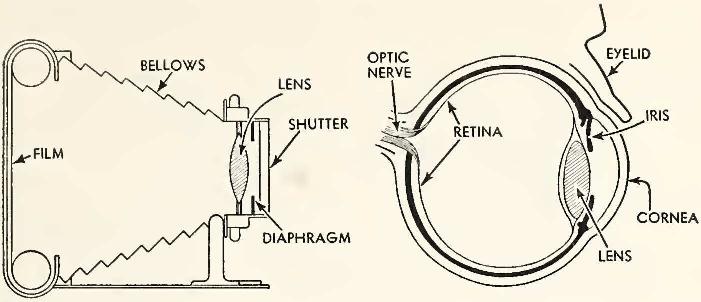
The convex lens is the most important of all aids to seeing. It is an essential part of the eye, of small telescopes and field glasses, cameras, projectors, microscopes, and magnifiers. Lenses are chiefly used to magnify objects and to project images.

What is a lens? A lens is usually made of glass or clear plastic. A convex lens is thicker in the middle than at the rim. A concave lens is thicker at the rim than in the middle. Both refract light.

Because a convex lens causes rays of light to come together or focus at a point, it will project an image. If you set up a candle, a lens, and a card, the candle and card may be moved so that an image of the candle falls upon the card. All rays of light from the tip of the candle which strike the lens focus at a point on the card. All rays from the base of the



A convex lens may be used to project a real image upon a card. Note that the rays of light are brought together or focused at a point.



The camera and the eye are similar in principle. The shutter corresponds to the lid, the diaphragm to the iris, the lens to the lens of the eye, and the film to the retina. What is the use of each part labeled?

flame focus at another point, and so on. The effect is to form an inverted image, which is a real image because it exists upon the surface of the card.

A concave lens spreads rays of light. It diminishes instead of magnifying objects seen through it.

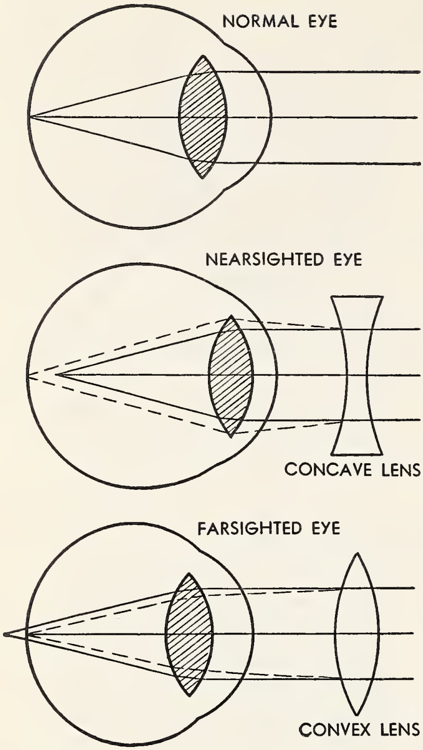
How does the eye refract light? The eye is a complex organ. It consists essentially of a convex lens, an opening or pupil through which light is admitted, and the retina in the back of the eye in which nerves are located. Each part of the eye is controlled by complex sets of muscles. Behind the lens is a dark chamber filled with fluid.

The light admitted to the eye is focused by the lens upon the retina. The lighter parts of the image set up strong nerve currents to the brain, but the darker parts set up less current or none at all. The pattern of the projected image is carried to the brain by the optic nerve. Where this nerve leaves the eye, there is a small blind spot. Some nerve endings are sensitive to light in proportion to brightness. Other nerves are sensitive to color.

The eye is often compared with the camera, for both have a convex lens which projects an image upon a surface sensitive to light, and a device for regulating the amount of light admitted.

How do eyeglasses correct eye defects? If the eye is too long, the rays of light focus in front of the retina. This condition, which is called nearsightedness, is corrected by use of a concave lens which spreads the light rays slightly. If the eyeball is too short, the rays focus behind the retina. This condition, which is called farsightedness, is corrected by use of a convex lens which brings the rays of light together.

Astigmatism is a condition caused by irregularities in the shape of the lens or cornea of the eye. For example, vertical lines may be sharply focused, while horizontal lines may be blurred. Corrective lenses are so ground that the irregularities of the lens or cornea of the eye are offset by



The lens of the normal eye focuses light sharply upon the retina. When the eye is not normal, use of glass lenses permits the error of the lens of the eye to be corrected.

a corresponding irregularity, but in the opposite direction, in the eyeglass.

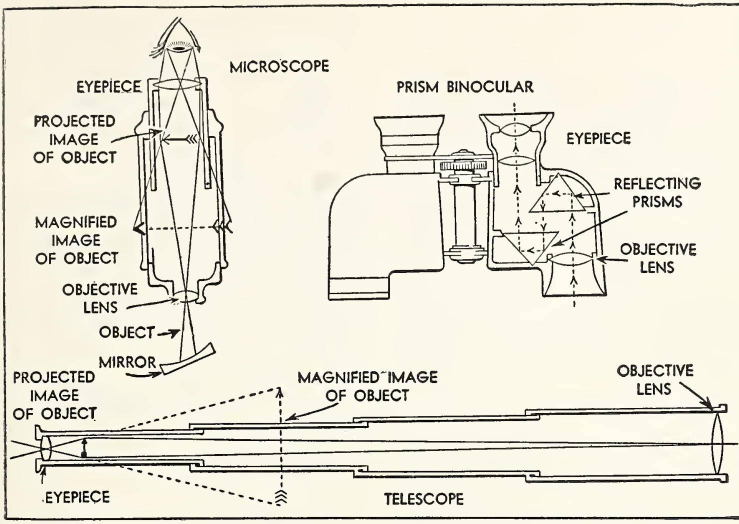
Correction of eye defects is of utmost importance. The muscles of the eyes have enough work to do without having to overcome defects which can be corrected by use of glasses. One should have his eyes tested only by a person who is highly skilled in his work.

How do lenses magnify? The common magnifying glass is a convex lens. It may be used for counting the number of weed seeds in samples of garden seeds, for looking at parts of flowers, for studying crystals in minerals, for counting threads in cloth, for observing dissections of specimens in the science laboratory, and for reading. In each case, light rays are collected and bent in such a way that the object is made to seem larger than it actually is. Magnifying glasses may be used as burning glasses.

By using a convex lens as a burning glass we can find its focal length. Focal length is the distance from the center of the lens to the surface upon which an image or light spot is focused. To measure focal length, the source of light must be at a great enough distance from the lens that the rays are parallel. A burning glass projects an image of the sun upon a surface. If a burning glass works best at a distance of eight inches, its focal length is eight inches. A thin, slightly rounded lens has a long focal length; while a thick, rounded lens has a short focal length.

The microscope has two sets of lenses: one set called the objectives, at the bottom of the tube, and another called the eyepiece, at the top of the tube. The microscope is a combination of magnifying glasses.

Microscopes usually have a number of combinations of lenses available, making possible different degrees of magnification. The microscope commonly



The paths of light rays through three common aids to seeing are shown in these diagrams.

used in general-science rooms magnifies from 40 to about 500 times.

Small telescopes are always made up of combinations of lenses. A telescope has an objective lens, which has a long focal length, and an eyepiece lens of shorter focal length. Telescopes are long—the distance between the lenses equals the sum of their focal lengths. A field glass is a pair of low-power telescopes mounted together. In binocular field glasses the light is reflected back and forth in the tube by prisms, making possible the use of a shorter tube.

The telescope used in astronomy inverts the image. If you were to look through it at a house, the house would seem to be upside down. In field glasses and telescopes used for looking at objects on the ground, another convex lens is used to again invert the image, making it right side up.

The opera glass is made up of a convex lens used as an objective and a concave lens at the eyepiece. The concave lens is between the focal point of the convex lens and the lens itself.

How are lenses made? Most of the lenses in use today are made of glass. Only the most nearly perfect pieces of special glass are selected for good lenses. The glass is ground by hand-controlled machines. Grinding is continued until in the best lenses of telescopes and cameras accuracies of 1/50,000 of an inch are obtained. Camera lenses consist of two to seven separate lenses placed in line. The cost of making good lenses is so high that

most people cannot afford them. Cheap lenses are not ground but are molded and polished.

Lenses are also made of a transparent plastic. The plastic refracts light as well as does glass and is cheaper to produce. The soft plastic is pressed by a hydraulic press into a steel mold and is as perfect as a glass lens ground by skilled workmen using expensive machines. After the mold is once made perfect, lenses may be formed in it cheaply and accurately.

Poor lenses focus part of the light in one place and part in another, producing blurred images and streaks of colored light.

How can you choose a field glass? A good field glass is of great value in nature study. It should be of not more than six power, and should have a high-quality objective lens of more than one inch in diameter. A large objective admits enough light to make it possible to see birds clearly when they are in the shade or to follow football plays on dark days. A prism binocular shows a wider field of view than does a field glass, but the field glass makes objects appear to be brighter.

DEMONSTRATION: HOW ARE LENSES USED?

What to use: Convex lenses, lens holder, candle, cardboard, concave lens, simple optical bench.

What to do: In a darkened room project an image of the candle flame upon the cardboard, following the information given in the text. Substitute another lens, and project an image. Which lens has the longer focal length? Examine the lenses.

Hold the thinner convex lens in the left hand and the thicker in the right hand, or put them in holders on an optical bench. Look toward some distant object, and move the two lenses until the object may be clearly seen upside down.

Pass a concave and a convex lens around the class, letting each pupil observe which lens magnifies and which diminishes the objects viewed through them.

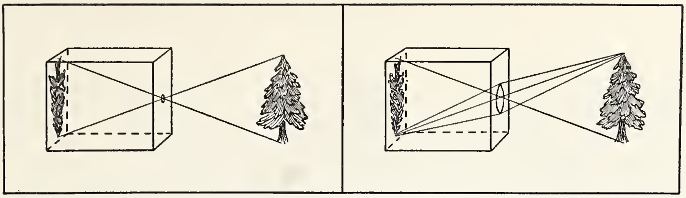
What was observed: Make simple sketches to explain what you observed.

What was learned: State four uses of lenses.

Exercise

Complete these sentences:

A concave mirror and convex lens are alike in that they —1— an image and —2— objects viewed with their aid. They are different in that the mirror —3— light and the lens —4— it. Images projected by lenses are —5— images. The —6— of a lens is the distance from the lens to the point at which the rays of light are focused. Images projected by lenses are —7— in position. The long eye is —8— and the defect is corrected by a —9— lens. The short eye is —10— and the defect is corrected by a —11— lens. Telescopes, field glasses, and microscopes are combinations of —12— lenses.



The advantage of a lens over a pinhole is that the lens admits more light and produces a much sharper image.

7. How is the camera operated?

The camera today is an essential tool of science. It is used for photographing the stars and other objects in space. The camera is also used with the microscope. In connection with the spectroscope it is used to determine the chemical composition of matter.

The scientific use of the camera does not compare in amount with the everyday use of the camera for pleasure. Photography is the leading hobby activity in the United States. Almost everyone takes pictures for the pleasure obtained from having them.

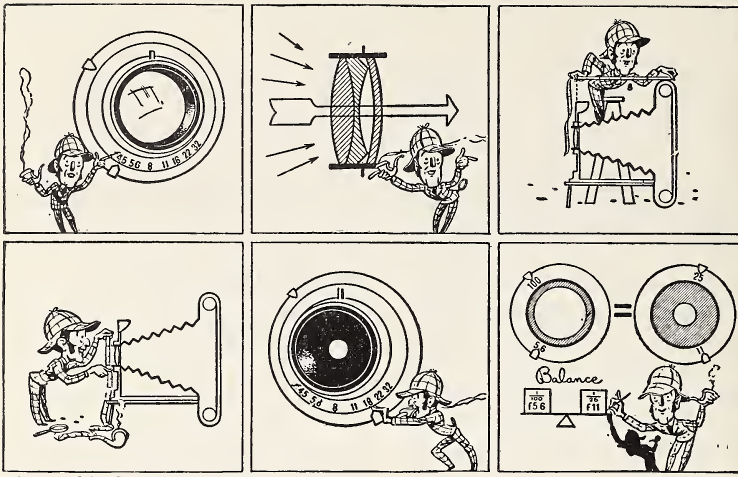
What is a camera? The first camera was a dark room—the name coming from the Latin *camera* (a room) *obscura* (dark). Light was admitted through a hole in the wall or window shade, and an image was cast upon the opposite wall. Today we make pinhole cameras on this same principle.

Ordinary cameras have convex lenses. The lens projects the image upon the film in the back of the camera. Advantages of using a lens instead of a pinhole are that a sharper image is obtained, and a large enough opening may be used to take the picture in a fraction of a second.

The box camera is a lightproof box with a lens placed at the front end. There are two rollers and a key for holding and turning the film which is placed in the back of the box. The shutter is a disk of metal with a hole in it, fitting over a metal plate with a hole in it. When you take a picture, the movable disk of metal is snapped past the plate, permitting light to shine through both holes into the camera for about 1/25 to 1/40 of a second.

Other cameras are essentially the same as the box camera but have devices for focusing, for regulating the size of the opening which admits light, and for regulating the time of exposure.

How is a camera focused? The ordinary folding camera has a scale of feet, either upon a screw in which the lens is mounted or upon the bed (the lower support when the camera is opened) of the camera. When the screw is turned in toward the camera, the focus is set for distant objects. When the screw moves



Pictures, The Snapshot Magazine

The number 4.5 is the largest opening of the lens. The distance from the lens to the film is the focal length. The focal length divided by the diameter is *f*. Both *f* and shutter speed may be adjusted on many cameras.

the lens away from the film, it is set for objects from 6 feet to 60 feet, depending upon the setting. You must guess the distance or measure it. If the focusing scale is upon the camera bed, the lens is moved back and forth by levers or other simple machines. Some expensive cameras are equipped with range finders to make focusing more nearly exact.

Some cameras are equipped with a ground glass back. When the camera is set up with the shutter open, the image is seen on the ground glass. When the picture is brought properly into focus and is pleasing to the eye, the shutter is closed and the ground glass is removed and replaced by the film held in a metal envelope or pack. The advantage of the ground glass is that you can see the picture before it is taken and can be sure it is in focus. Most professional photographers use this type of camera.

In another type of camera the image is reflected by a mirror and focused on a piece of ground glass at the top of the camera.

How do we set the camera for correct exposure? The aperture is the opening in the metal plate through which light is admitted. The amount of light admitted depends upon the size of the opening. The size of the aperture is indicated by the small letter *f*. The *f* value is obtained by dividing the focal length of the lens by its diameter. That is, if the lens forms the image upon a film four inches behind it, and the lens is one inch in diameter, the *f* value is 4 ($4 \div 1 = 4$). If the diameter

This picture was taken at f 5.6 at 1/300 of a second. What does this information mean? Note that the action of the galloping horses is stopped.

of this lens were one-half inch, the *f* value would be 8.

The *f* numbers on a camera are usually 32, 22, 16, 11, 8, 5.6, and 4.5. The smaller the number, the larger the lens. The box camera has an *f* rating of 16, and some ordinary folding cameras have a rating of 6.3. The larger the lens, the more expensive the camera. The aperture is set by moving a pointer.

The shutter is a set of metal leaves which open and close. The better shutters are operated by clockwork made as carefully as that of a fine watch. Cheaper shutters are operated by a simple spring. Ordinary folding cameras have three time settings: 1/25, 1/50, and 1/100 of a second. More expensive shutters have time settings ranging from one second to 1/200 or 1/800 of a second.

The bulb setting permits the camera aperture to remain open as long as you hold your finger on the lever. For all exposures slower than 1/25 of a second, you must support the camera upon a tripod or some other solid support.

To obtain correct exposure, one must adjust both aperture and exposure time, after setting the lens for distance. The correct exposure depends absolutely upon the amount of light reflected by the object.

Guides and tables for correct outdoor and indoor exposure can be bought for ten to fifty cents at photography stores. These guides are so dependable that you will rarely make a mistake if you learn to use them correctly.

What equipment should we choose? There are in general two types of black and white film for sale. The *orthochromatic* [ôr′-thȯ·krȯ·măt′ĭk] film names end in *chrome.* Since these films are not sensitive to orange and red

light, orange and red objects photograph black. Orthochromatic films are designed for outdoor photography and ordinary snapshots. The *panchromatic* films are sensitive to all colors and are used indoors and to photograph all objects containing red or orange coloring.

Filters are pieces of colored glass which are slipped over the lens. They may be used with panchromatic films. To make the sky dark and clouds white a yellow filter is used. A red filter makes the sky almost black. Exposure must be increased when a filter is used.

For a few dollars you can buy a box camera that will take satisfactory pictures. For several dollars you can buy a better box camera, with a built-in yellow filter, a flash attachment, and a lens that will take pictures near or far. There is no use in buying a folding camera unless it has a lens opening of at least *f* 6.3. Such cameras are fairly expensive. Good roll film cameras, with *f* 4.5 lenses and shutters with speeds from 1 second to 1/200 of a second, are expensive but desirable.

A cheap candid camera, which uses a 35-millimeter film, is a poor buy. Most low-priced cameras of this type are poorly made and have cheap lenses. Even fairly good small cameras cost more than $50. All small cameras take pictures too small to see without having them enlarged. The resulting enlargements are rarely entirely satisfactory. Most beginners will get much better pictures with a box camera than with a candid camera.

The best film for most pictures is 2¼ by 3¼ inches in size with eight exposures in a roll. Pictures of this size are suitable for album use without enlarging, and the film is available at all drugstores.

Can we use color film in photography? There are two kinds of color film available. One kind will produce a transparency in the same colors as the original scene, and is viewed by holding it toward a bright light or by projecting it on a screen. The other kind is used to make color prints, and the film serves as a negative.

Color film is usually slower than black and white film—that is, it requires longer exposures. It does not give good pictures in shadows, which too often appear black instead of in color. In order to use color film a better camera is required than for satisfactory black and white pictures. Color film is expensive. Many color pictures are not in true colors. Some color prints fade with time. You cannot ordinarily develop and print color pictures at home unless you are willing to spend much time and money.

It is likely, however, that as improvements are made in color films they will replace black and white for many uses.

Exercise

Complete these sentences:

A —1— is a lightproof box, into which light is admitted through a —2—. An image is projected by the

—3— on a sensitive —4—. The position of the image is —5—. The inside of the box is black to prevent —6— of light. The —7— of the lens is the distance from the lens to the film when properly focused on a distant object. The aperture, or *f* opening, is obtained by dividing the —8— by the —9— of the lens. The amount of light that enters the camera is controlled by the —10— and —11—.

8. How are good pictures made?

There is more to making a good picture than being able to operate a camera. Operation of the camera must first be learned, but making a picture is the goal.

How can you take a picture? The camera records everything in the scene impartially—the electric light wires, the billboards, the hydrants, the hole in the sidewalk. Until one studies snapshots, he does not realize how unsightly most familiar scenes really are.

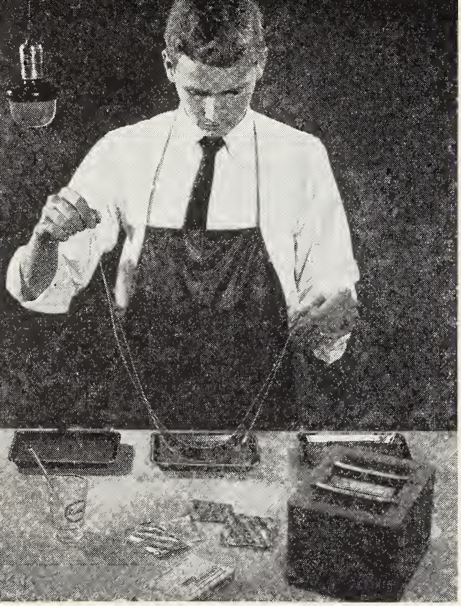
The best light for taking pictures comes from the side and slightly behind the camera. Light from directly behind the camera rarely gives pleasing pictures. Light from in front of the camera often gives pleasing pictures, but great care must be taken to prevent light from shining on the lens. A shade must be used when the camera points toward the light.

Try to avoid getting too much into your picture. A good picture has one and only one center of interest. Plain backgrounds are advisable. For example, if you want to take a picture of your cat, place a white or gray cardboard or a sheet behind it.

How can you develop the film? If you should examine an exposed film by a very dim light, you would see no picture on it. Although the sensitive silver salts upon the film have been changed by the light, the picture is incomplete.

A solution of chemicals called the *developer* is used to bring out

This snapshot includes several common errors. The picture is bad because of the shadow of the photographer, the tail of the second cat, the unsightly background, the crude box, and the location of the cat above the center of the picture.



This simple darkroom set makes possible the development of films and the printing of pictures. Note how the film is held. Development of film is easier if deeper trays or bowls are used for the developing chemicals.

the image on ordinary black and white film. The steps in developing film are simple.

Mix the developer as directed on the package or tube. Put it in a glass, enamel, or hard-rubber tray. Mix an acid-fixing solution, also called acid hypo, according to directions, and pour it into a second tray. Fill a third tray with water. Solutions should be kept below 70 degrees Fahrenheit.

Put the trays where you can find them in the dark. The bathtub is a good place. Make the room absolutely dark, and wait one minute to check for stray light. Cover all cracks around doors and windows.

In the dark, take the film from the spool. To do this break the seal, and unroll the paper until you can feel the film with your fingers. Separate the film and paper, and when you come to the end of the film, tear it from the paper and throw the paper away. The film is stiff and springy. Hold it carefully to keep it straight.

First, wet the film thoroughly for half a minute in clear water.

Second, holding the film by the ends, as shown in the picture, dip it into the developer. Moving the hands up and down, run the film through the developer. Continue this, in the dark, for the length of time stated on the package, which will be between 3 and 20 minutes. Have some person in an adjoining room keep time, or count the seconds. You can do this with practice.

Third, at the end of the developing time, rinse the film in water for half a minute.

Fourth, run the film up and down through the fixing solution several times. Keep it covered with the hypo for 15 minutes, moving it occasionally. You may look at the film by dim light after it has been in hypo five to ten minutes.

Fifth, after 15 minutes of fixing, transfer the film to water, and wash it in cold running water for one hour to remove the fixing solution. Ten changes of water are necessary for complete washing.

Sixth, dry the film by hanging it where no dust will fall on it.

The film may be held in a strong spring clothespin and hung on a cord run through the spring. Surplus water may be wiped off with a piece of *damp* cotton. The film dries in four to eight hours.

What happens during development? While you were moving film through the developer in the dark, the image was being formed. The silver salts which were exposed to the light were slowly changed to tiny grains of pure silver on the film. The silver grains are black and form the image. Just as the pictures in this book are made up of dots, the picture on the film is made up of grains of silver. The light portions of the original scene are darkest, and the dark portions lightest on the film, which is called a negative.

The fixing solution stops the development of the image and dissolves from the film the undeveloped silver salts upon it.

The silver salts are held in an emulsion of gelatine which is coated upon the film base. Because gelatine dissolves in warm water, it is particularly important to keep the film cool. The warmth of your fingers may melt the emulsion from the film.

A camera is available which contains not only film but developing chemicals. A complete picture, fully developed, can be taken from this camera soon after the picture is taken.

Can you check correct exposure? You can check your exposure if you can obtain use of an exposure meter or light meter.

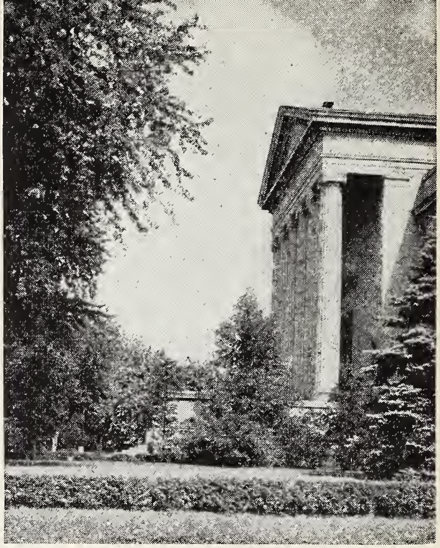
General Electric Company

With an exposure meter it is possible to measure the per cent of light transmitted by a negative. Films which transmit 10 to 20 per cent of light may be considered properly exposed for easy printing.

Note the reading of the meter as it is near a light. Then put your film over the sensitive cell, and read the amount of light shining through the film. A properly exposed and developed film lets through about 10 to 20 per cent of the light falling on it.

How can you make a print? To make a print, you need printing paper, a printing frame, and solutions of developer and hypo. Fresh developer should be mixed. Some developers are used for both film and paper; others for only one. Hypo can be used several times if kept clean. No metal or rust should come in contact with any photographic chemical.

Printing is done by red light,



In the negative (*left*), the dark objects appear to be light and the light objects appear to be dark. In the positive, the brightness appears as seen by the eye.

such as is given off by a ten-cent $7\frac{1}{2}$-watt red bulb. In a room that is dark except for the red light put the film in the printing frame, with the shiny side against the glass. On top of the film put the printing paper, with the shiny side toward the film. Put the back of the printing frame in place. If you want white borders on your print, cut out a black paper frame to cover the edges of the paper.

Hold the printing frame at right angles to, and one foot from, a 25-watt lamp, and turn on the light. After 10 seconds, turn it off. Take the paper from the frame and put it in the developing solution, leaving it exactly 45 seconds. Put the print in rinse water for five seconds; then move it to the fixing solution. It must remain in the fixing solution for 15 minutes.

If your print is too light or too dark, make others—exposing for longer or shorter amounts of time—until you get one that is exactly right in tone.

The print is washed for an hour in running water or in 10 changes of water. If you have a glossy paper, dry it on a polished ferrotype plate. Place the print face down on the metal plate, and roll it dry with a rubber roller. The print dries, curls up, and comes off. If the finish is not to be glossy, dry the print on a cloth or a blotter.

DEMONSTRATION: HOW ARE PRINTS MADE?

What to use: Acid hypo, Eastman universal developer, trays, negative, red light, printing frame, print paper, white light, or Eastman daylight print paper.

What to do: In the darkest room available—one without any light—set up the apparatus for printing pictures, and proceed as directed in the text.

If you use daylight print paper, you will not need to darken the room, but you will need a bright light for printing.

What was observed: Write a brief description of the process of printing.

What was learned: What kind of changes produce pictures?

The camera most commonly used by news photographers and other professional workers is equipped with flash holder, range finder, and many adjustments for taking pictures under a variety of conditions.

Exercise

Write a paragraph summarizing this problem, using in it the following words: fixing solution, developer, water, negative, paper, light, red light, 15 minutes, 45 seconds, one hour, positive, drying.

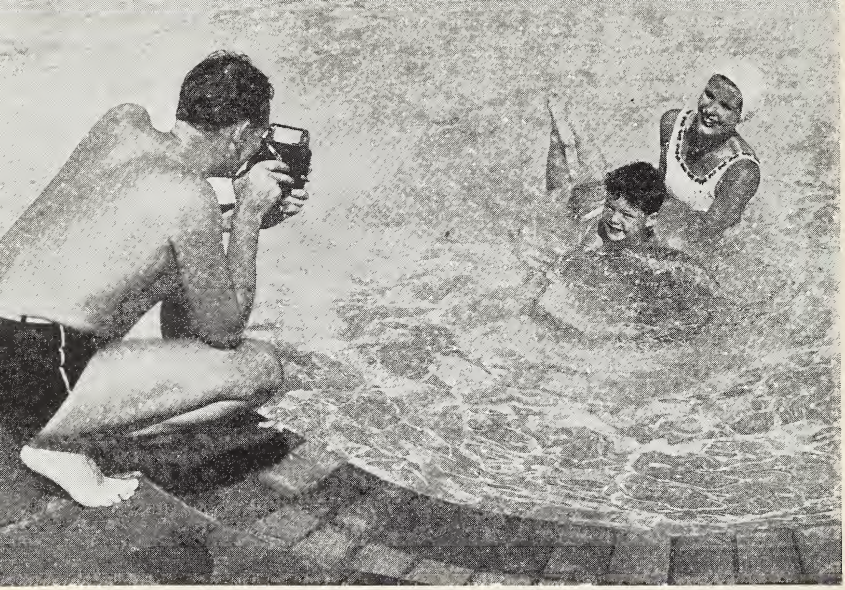
9. How are motion pictures made?

Today making and showing motion pictures is a major industry. It employs thousands of people in studios and more thousands in theaters. In one recent year more than half-a-million miles of motion picture film was manufactured in the United States. More than half the silver mined in this country was used in manufacturing film.

The motion picture ranks along with the telescope, the microscope, and the spectroscope as an important scientific tool. The motion picture camera reduces or increases speed, giving us a chance to see those things we otherwise would never observe. The opening of a flower is so slow that no person can see its growth, yet, by taking a picture every half-hour over a number of days, the action can be shown in a few seconds on the screen. The development of a chick in an egg has been speeded up for observation.

The speed of objects moving too fast to be observed is slowed down. Motion of the piston in an automobile cylinder or of a bullet leaving a gun cannot be observed directly by human eyes.

The camera combined with the microscope gives opportunity to study many objects difficult to see with the eye. Unusual objects in nature may be studied and recorded best by motion pictures. Difficult technical processes are



Most amateur motion pictures are taken to record important personal events, such as when a child learns to swim. The camera is held fairly steady by resting the elbows on the knees.

photographed and studied to learn methods of improving them.

How are motion pictures made? The motion picture camera does not take motion pictures. Instead it takes a series of still pictures at a high rate of speed. The camera part of a motion picture machine is about the same as a good still camera.

The exposure time of a motion picture camera operating at normal speed is about 1/35 of a second. A rotating shutter makes the exposure automatically when the camera is operating. The film is moved between exposures, thus placing the next frame in position to be exposed. Sixteen complete exposures are made each second at normal speed. For slow motion 32 or 64 exposures are made per second. No matter how many exposures are taken in a second, they are shown at the rate of 16 to 24 frames per second.

The motion picture camera is equipped with a motor and a film holder. The motor is usually spring operated, and it moves the film and operates the shutter. The film is wound through the camera from one spool to another. It may or may not be enclosed in a magazine (a closed box). A magazine may be put in or taken out of the camera at any time without spoiling the film.

The film has a series of holes along the edges into which sprocket teeth fit. There are 16

frames per foot and 4 holes per frame in the large-sized film. The sprockets which move the film catch in the holes.

Cameras are made in three standard sizes. The commercial studio camera uses a 35-millimeter film. The standard amateur and educational size camera uses 16-millimeter film. Because of its smaller size, the 16-millimeter camera is less expensive to operate and easier to handle. But the pictures, being one-fourth the area of the 35-millimeter picture, are not fully satisfactory for theater projection. An 8-millimeter camera is popular when low cost is the most important factor. It takes pictures which are fairly satisfactory to most people for use in the home, and it is small enough to slip into the pocket.

Inexpensive cameras have one lens which is used for all purposes. More expensive cameras have three lenses mounted on a circular pivot in such a way that they can be changed by turning them into place. One lens is used to take pictures at close range, one for normal distances, and one for distant objects. This third lens is called a telephoto lens.

The cost of developing amateur movie film is included in the cost of the film. The process of development is somewhat different from that used on ordinary film. The picture is brought out as a negative, then reversed so that it becomes a positive. The film you send in to be developed is returned as a positive.

Why do pictures seem to move? The eye is easily deceived. Sixteen times a second a nerve impulse travels from the retina along the optic nerve to the brain. Even though an object may not remain before the eye, the image stays on the retina for about 1/24 of a second. While the image from one picture is still on the retina, the screen is darkened, and another picture is moved into place in the projector. Another picture seems to fit into the motion instantly, although actually the screen is dark almost half the time.

The darkness lasts about 1/32 of a second, and the picture is shown for an equal length of time. If the film is run too slowly the pictures flicker, and we become aware of the intervals of darkness.

Is color photography practical? Color photography is today the most interesting of all fields of motion picture making. The color film is too complex in structure to describe here. It has three or more coats of chemicals sensitive to various colors of light. Such film is developed only by the manufacturers. Although it is entirely probable that great improvement is still to be made in color photography, the films now available take satisfactory pictures.

Can you make good motion pictures? Many people are now producing their own motion pictures. Cheap movie cameras, while not especially good, are in common use. Cameras may be rented in many cities. If you wish

to make a satisfactory movie, you must use the right methods.

First, you must be able to take a picture and to know what will make a good picture when you see one. The same rules of planning and choice of background apply to motion pictures that apply to still pictures.

Second, you should have a story. If you want to take a picture of a person, don't have him stand grinning into the camera. Have him do something that he ordinarily would do. If your picture is to be rather long, write a scenario—an outline of the story—and practice acting it before you take the picture. Mix close-ups into the action freely.

Third, you must operate the camera correctly. Have enough light, and set the aperture correctly. Most indoor pictures taken by beginners are underexposed. Be certain that you know how the camera works before getting people in place.

Fourth, hold the camera still. If possible, use a tripod. Never take movies from a moving automobile. Don't swing the camera around to get in all the scenery in one shot. Pictures taken while moving the camera are blurred. The picture should be taken for 10 seconds with the camera in one position. Then it should be stopped and moved to a new part of the scene. The only time the camera should be moved is to follow moving objects.

How long do films last? Motion picture films do not last indefinitely. At the end of five years they may be cracked and dry. They rarely last more than 10 years unless given exceptional care. Films should be reprinted when necessary. The film requires a reasonable amount of humidity to be kept in best condition.

The still camera has an advantage over the motion picture camera when a permanent record is desired. Pictures taken of the War Between the States are still in good condition, but the original motion pictures of the World War of 1914–1918 are not in usable condition.

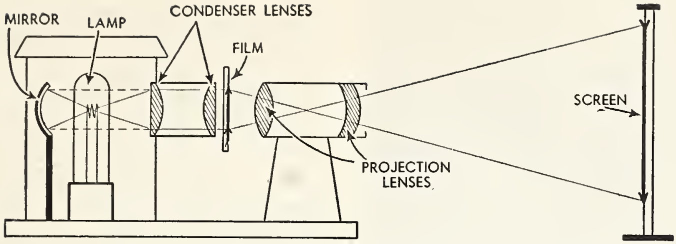
Exercise

Complete these sentences:

The spring-operated —1— of a motion picture camera operates a rotating —2— and moves the —3— along in a series of jerks. Standard rate of taking motion pictures is —4— frames per second. The standard speed of exposure of a motion picture camera is —5— of a second. Pictures are —6— if the camera is moved in use. The film is reversed in —7— so that the film you take comes back to you as a positive. Images stay on the retina about —8— of a second.

10. How are pictures projected?

There are several uses for projectors of pictures. The motion picture projector, the film strip projector, the glass slide projector, the postal card projector, the enlarger, and the film reader are



A projector works in a way opposite to that of a camera. The film is brightly lighted and its image is projected by convex lenses upon a screen.

all fundamentally the same machine, each adapted to the particular uses to which it is put.

How does a projector work? There are three parts to projectors. The first is a source of light, the second a device for holding and controlling the film, the third a set of lenses for projecting the picture.

There are two types of light sources in general use. The diffuser type consists of a box in which the lamp is placed, with an opal glass over the opening. The condenser type, which is much more efficient and gives sharper detail in the picture, consists of a set of lenses which concentrate the rays of light from a lamp on the film in parallel lines. A concave mirror behind the lamp also directs rays of light into the lenses. The special lamp used in the condenser system must be placed exactly in focus in relation to both the lenses and the mirror. Light passes through the film and is projected by the projection lens on the screen. The dark parts of the film are projected as shadows, the light parts as bright spots. The lens must be of good quality and quite large to permit enough light to pass through. A poor lens causes blurring. Projection lenses are made up of two or more convex lenses.

How does the motion picture projector work? The projector which shows movies in your school auditorium or local theater is provided with a condenser type of light system. In large theaters arc lamps are used instead of Mazda lamps because they give a more brilliant source of light.

The projector is almost exactly the same as a camera in operation, except that the light passes through it in the opposite direction. The shutter is of the revolving type which moves past the opening of the lens and alternately darkens the screen and permits the beam of light to shine on the screen.

The film is mounted on a reel and led over a toothed sprocket which fits into the holes of the film. A loop is formed to provide slack. The film passes through guides and through a gate behind the lens. The shutter opens, the film is still, and the picture is shown on the screen. When the

Preparing for an evening of fun with motion pictures, these people are setting up a projector for amateur films.

shutter is closed and the screen is dark, the film is moved and wound on another reel. The film must be wound back to the first reel before it is used again. Some projectors may be stopped to show single frames or run backward.

All except the least expensive projectors are operated by electric motors. The others are operated by hand cranks.

The "photograph" of sound is carried on the edge of sound film projected into a radio system and is changed into sound.

How do still-picture projectors work? The film strip projector has a condenser illuminator, equipped with a prefocused Mazda lamp. The film is placed on a spool and run through a gate provided with guides to hold the film in place. The film is moved by a hand-operated sprocket. Filmstrip is made on short lengths of motion picture film.

The most practical way to view color film is by projection. The pictures, taken with a 35-millimeter camera on motion picture color film, are developed into a colored positive and projected on a screen through a filmstrip or small slide projector.

The glass slide projector is like the others, except that because the slide is larger, a larger lamp is required to illuminate the picture, and larger lenses are required. The photograph is printed on a piece of glass coated with an emulsion. To protect the emulsion from injury, another piece of glass is bound to the photograph with black cloth tape.

The slide is placed in a drawer-type holder, which slides into a slot behind the lens.

In the postal card projector light is reflected from the card through the projection lenses. Lamps are placed in the projector and screened from the lens. Usually two 500-watt lamps are used, set at 45 degrees to the card, one on each side of the lens. This strong illumination is required because the postal card absorbs from 80 to 90 per cent of the light. A total illumination of 1000 watts in a postal card projector is equal to about 200 watts in a film projector.

What is the enlarger? The enlarger is a projector, exactly the same in principle as the glass slide projector. Illumination is

provided in the usual enlarger by a lamp, and a piece of opal glass is used to diffuse the light. Some enlargers require use of photoflood lamps, some use Mazda lamps, and some use circular fluorescent lamps.

A negative is put into a slide made of two pieces of glass in a frame. The dull or emulsion side of the negative is turned toward the lens. The picture is projected upon a piece of white paper and brought into focus. When the arrangement of the picture seems pleasing, and it is properly focused, the enlarger light is turned out. Then by red light a piece of photographic enlarging paper is put in the place of the white paper. The enlarger light is turned on, and the picture is projected upon the sensitive paper. Exposure ranges from two seconds to one minute, the length of time depending upon the brightness of the light, the density of the negative, and the type of paper used. Enlarging paper is 500 to 1000 times faster than print paper.

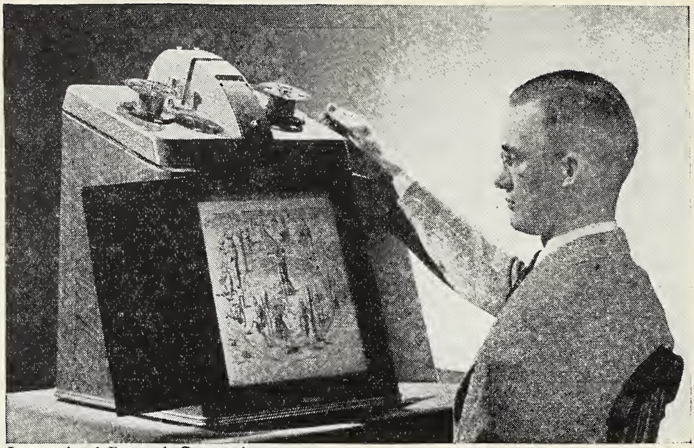
The exposed paper is put into developer for 45 seconds or 1½ minutes, depending upon the type of paper used. It is then rinsed and fixed in the acid-hypo solution, washed, and dried just as a print is.

Most enlargers are mounted on a rod with the lens pointing down, and the paper is placed on the table. Many owners of cameras with removable backs use their cameras as enlargers. They make a light box and film holder, and use the camera for the lens and focusing device.

This modern enlarger uses a fluorescent lamp for a light source. The image of the film is projected on the paper holder.

Enlarging permits one to select a small part of a negative to make a large picture. It also permits one to shade, brighten the light, and otherwise control the printing of the picture.

What are film readers? Many libraries are now recording books and magazine articles on film. An expensive camera of excellent quality using 35-millimeter film is used to photograph the books. Two pages are copied on a double frame, making a picture about 1 by 1¼ inches. An entire book may be photographed on a comparatively small roll of film. Rare and expensive books may be photographed to save them from handling. The cost of pho-



International Research Corporation

In a film reader an image from a 35-millimeter film is projected upon a diffusing glass screen.

tographing one book is much less than the cost of printing it.

The print on the film positive is read in a film reader. This device is a small projector inside a box. It contains the usual lamp, lenses, and film holder. The print is projected upon a piece of ground glass which is mounted in the box itself. The film reader is a compact filmstrip projector.

Many banks and business firms keep their records on film in order to save space.

Exercise

Make a table by ruling your paper into five columns. Head the columns as follows: TYPE OF PROJECTOR, LIGHT SOURCE, HOW LIGHT IS CONTROLLED, FILM HOLDER, LIGHT PROJECTED UPON. *Fill in the first column with the names of the projectors mentioned in this problem, and complete the table by describing the projectors with these words:* Mazda, photoflood, arc, condenser, diffuser, slide, guides and ratchets, screen, ground glass, photographic paper.

A review of the chapter

Light is a form of radiant energy which travels through space in straight lines with a wave motion. White light is made up of waves varying in length from 400 to 700 light units. Violet light has the shortest wave length and the most energy. Red has the longest wave length and the least energy. White light may be separated into colors by the prism.

Light for indoor use should

be brighter than 10 foot-candles, should be uniform in all parts of the room, and should be free from glare.

Light is reflected by surfaces through which it does not pass. Mirrors reflect light. Concave mirrors are used in headlights, in telescopes, and in magnifiers. Plane mirrors are used for viewing ourselves. Convex mirrors are used for some rear-view automobile mirrors.

Light is refracted by passing through substances of differing densities. A convex lens focuses light rays, and it is used to project images or magnify objects. Concave lenses are used to diminish size of objects.

Because light is a form of energy it can be changed to other kinds of energy. The light meter uses light to produce electrical energy. Light can also produce chemical changes.

Light is used in photography, for producing changes in the chemicals on film and paper, and for projecting images on screens.

Word list for study

wave length	acid hypo	focus	glare
translucent	enlarger	spectrum	reflect
mantle	emulsion	astigmatism	concave
neon	opaque	*f* value	refract
inversely	polaroid	projector	lens
incidence	fluorescent	film reader	shutter
convex	foot-candle	transparent	developer
spectroscope	indirect	incandescent	sprocket
magnify	diffuse	photoflood	condenser
aperture			

How does a negative differ from the positive of a photograph? In how many ways is the negative the reverse of the positive?

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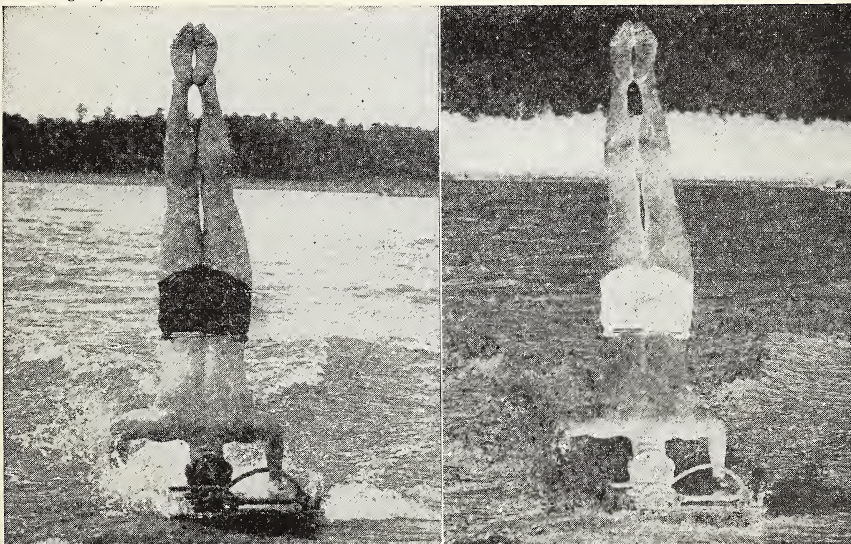


An exercise in thinking

Write the numbers from 1 to 37 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Light is a form of radiant energy that travels in waves which move in straight lines through space.

B. Color of light is dependent upon its wave length, violet having the shortest and red the longest waves.

C. The color of an object depends upon which light waves it reflects, absorbs, or transmits.

D. The angle of incidence equals the angle of reflection.

E. The brightness of light is inversely in proportion to the square of the distance from the source.

F. Light is refracted when it passes from one substance to another of different density.

G. Light may produce physical and chemical changes.

H. Light is given off by incandescent objects.

I. Light is given off as a result of electrical discharges through gases.

List of related ideas

1. Light changes the silver salts upon film when a picture is taken.
2. A light meter produces an electric current when light shines on it.
3. Some lamps give off light from hot mantles.
4. Hot carbon particles in a flame give off light.
5. Polaroid separates light in one plane from light in other planes.
6. In fluorescent lamps electricity passing through mercury vapor produces ultraviolet energy.
7. A single lamp in a room is usually an inadequate source of illumination.
8. Light falling upon a dark ceiling is changed to heat.
9. The objects in a mirror appear to be reversed.
10. We sight guns by use of light rays.
11. Northern lights appear in the sky where the air is thin and electricity is present.
12. Tungsten or wolfram is used in electric lamps because it withstands high temperatures.
13. When light is reflected, its direction is changed by an object through which it does not pass.
14. A prism separates white light into colors.
15. A concave mirror focuses light rays.
16. The cloudless sky is blue.
17. Concave lenses are used in glasses to correct nearsightedness.
18. A red object absorbs wave lengths of from 400 to 600 light units.

19. We should sit relatively close to study lamps.
20. The neon lamp produces light without becoming hot.
21. We can see the dim moon only because it is fairly near us.
22. We must aim below an object in water if we wish to hit it.
23. Dust in the air diffuses light by reflecting it in all directions.
24. The vapor in a carbon arc gives off light.
25. Men in deserts sometimes see lakes where there are no lakes.
26. A black object absorbs almost all light which falls upon it.
27. Almost all glass is a filter in the sense that it shuts out some kind of radiant energy.
28. Light may be changed to heat.
29. When light loses energy, as in passing through space, it becomes redder.
30. Telescopes are often made of two or more lenses.
31. Light fades many kinds of cloth.
32. We sometimes see rainbows in the sky when sun shines on raindrops.
33. A film reader is a kind of projector.
34. The biggest telescopes contain mirrors.
35. A light with a brightness of 100 foot-candles at a distance of one foot gives a brightness of one foot-candle at 10 feet.
36. We use convex lenses to correct farsightedness.
37. A convex lens projects a real image.

Some things to explain

1. Why does a red filter cause a blue sky to look black in the finished print, while the white clouds look white?
2. What is the chief advantage of the new fluorescent lamp over the older Mazda lamp?
3. What are the three kinds of eyeglass lenses, and for what are they used?
4. Why can you take a picture in a shorter time with a camera with a lens than with a pinhole camera?
5. Find five different sources of glare in your schoolroom and work out ways of removing them.
6. Why do people sometimes suffer from snowblindness?
7. Can pictures be taken in the dark? Explain. Can you see in the dark? Are there invisible radiations? Explain.

Some good books to read

Bendick, J., *Making the Movies*
Bragg, W. H., *Universe of Light*
Compton's Pictured Encyclopedia
Crouse, W. H., *Understanding Science*
Eastman Kodak Co., *How to Make Good Pictures*
Morgan, A. P., *Boys Book of Science and Construction*
Morgan, A. P., *A First Electrical Book for Boys*
Sussman, A., *Amateur Photographer's Handbook*
Teale, E. W., *Boys Book of Photography*
Whitman, W. G., *Household Physics*
World Book Encyclopedia

George School

UNIT THREE

LIVING IN GOOD HEALTH

Mabel had test tubes, some glass saucers, a can of ether, and some bottles arranged on the table when the class was ready to observe her demonstration. As she worked she explained what she was doing: "I am sure that I am working with materials well liked by all of you—that is, foods. I am going to test egg yolk and peanut butter for fats. First I fill the test tube about one-fourth full of ether. This is the same kind of ether that is used to put people to sleep for operations, and it is also explosive. You notice that I use no flame in this experiment. First I will grind some peanuts to make peanut butter. Now I am putting about one fourth of a spoonful of peanut butter into the ether. Ether will dissolve fats from foods."

As she talked she put her finger over the end of the test tube and shook it vigorously for perhaps half a minute, and then put the tube on the rack. She explained, "While the peanut butter is settling I'll prepare another test tube with egg yolk as the food tested. Observe that I have it already cooked hard, and crumbled."

By the time the egg was ready, the peanut butter had settled. Mabel poured the clear ether from the test tube containing peanut butter into a flat dish and carried it to the window, where she put it on the sill outside the room. She said, "Ether evaporates rapidly. Now I'll extract the fat, if there is any, from the egg yolk while I'm waiting."

She shook the egg yolk into the ether and put it on the rack to settle. Then she brought the glass dish from the window sill, and laid a piece of paper on it. She held the paper before the window.

She explained, "The fat extracted from the peanut butter makes a large grease spot on the paper, which you all can see."

She then completed the test of the egg yolk in the same way.

CHAPTER

5

Building a Healthy Body

Your body is just about all the equipment you have with which you can carry on the important work of living. It is already nearing its completed form and size. The next few years will provide your last opportunity to influence its growth. The condition of your body, fortunately, is not something that is entirely beyond your control. You cannot change your final size greatly, nor your body proportions to any marked degree. But you can keep yourself well fed and can make the best use of whatever abilities you may have. You can understand the needs of your body in order to direct your efforts wisely. You can perhaps free yourself of superstitions and fears which have been worrying you.

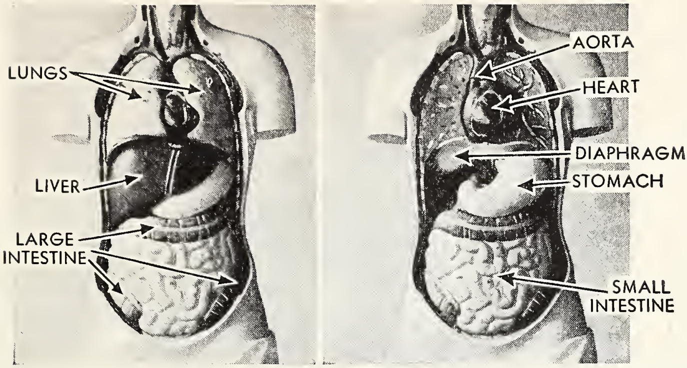
An understanding of the needs of the body for growth and health is of great importance to both boys and girls as future parents. Each generation in the United States, from about 1880 to 1950, has been larger and generally healthier than the preceding generation. This gain has been largely due to proper use of foods for both children and adults. The average girl baby born today will probably live to age 70, and the average boy baby will live to age 65. This expectancy of long life is in part due to better living conditions, sanitation, and medical care. It is also due in part to better understanding of the importance of good care for the body and of good food.

Some activities to do

1. Obtain whatever models and charts of the human body that are available in your school, and study them in detail. Make sketches of some of the more important parts of the body, and learn their functions.

2. Read the directions for testing foods as explained in this chapter, and test as many foods as you can.

3. If you can obtain some small white rats or mice, set up a feeding experiment. Feed one group white bread, meat, and milk. For a second group substitute soft drinks for the milk. Feed a third group a balanced diet of vege-



Does your school own a model like this? The first view shows the organs in place. The second shows part of the lungs removed to expose the heart, and the liver removed to show the stomach.

tables, cereals, meat, and milk. Keep records of weight gains and general appearance of the rats.

4. Obtain two flowerpots and some wheat or oat seeds. In one flowerpot put the best garden soil you can obtain. In the other put a soil of sand and clay which has been washed in water for some time. Plant seeds in the two pots, and observe the difference in growth and appearance of the plants.

5. Measure the water content of foods. Obtain and weigh several food samples. Dry them for several days over a hot radiator or, very carefully and without scorching, in a warm oven. Weigh them when they are dried, and calculate the per cent of weight lost.

6. Learn how to teach a dog or other animal some trick. Bring the animal to school for a demonstration, and explain your methods.

7. Make a model tooth of soap, showing in cross section how it is constructed.

8. Measure the height of boys and girls in the class. Find the average height. How does this compare with the heights of the fathers and mothers of class members? Make careful observations, and write up a report of your findings.

9. Make a sketch of the kidney in your notebook, being careful to label the parts exactly; or make a large drawing to use as a class chart.

10. Count the calories in average-size helpings of meals taken from a newspaper menu to see whether it is well planned from this point of view.

11. Prepare a diet for one week for a high school girl who is 20 pounds overweight (1200 to 1500 calories), being very careful to provide enough minerals, vitamins, and proper balance.

12. Provide a diet for a high school boy who wishes to gain weight to make the football team (3500 to 4000 calories), keeping the matter of balance in mind. Plan one week's menu.

13. Ask your butcher to save you the lungs of a chicken. Put a glass tube

into the opening of the lung tubes, and blow on it to show how the sacs expand. Does lung tissue float? Look at it under a microscope, if one is available.

14. If a microscope is available catch a live frog and examine the circulation of the blood in the web between the toes of the frog's hind foot. Keep the frog wrapped in a wet towel, and after the demonstration turn him loose where you found him. Ask the teacher to help you keep the frog quiet.

15. Obtain an animal heart from the butcher. Clean it by soakng it in salt water overnight. Demonstrate to the class the arteries, veins, valves, auricles, and ventricles.

Some subjects for reports

1. Discovery of the vitamins
2. The diets of people of other countries
3. The special values of several kinds of foods
4. The importance of diet to athletes
5. Relation of diet to good teeth
6. Relation of diet to healthful skin conditions
7. The discovery of the circulation of the blood
8. Advertisers' claims and the truth about several foods
9. The development of the science of anatomy

1. What is the human body?

Have you heard the human body compared to an engine or a machine? There is only slight reason for such a comparison. The body takes in food and the engine burns fuel. Both release energy, and both the body and a machine contain some levers. But here the comparison ends. The body regulates itself, repairs its own worn parts, makes the chemicals needed to keep it in good condition, and directs its own movements. The real difference between the human body and an engine is that the body is alive and an engine is not.

What are the parts of the body? The body is really a great collection of cells, each capable of doing some particular thing. One cell alone cannot do much, for cells are small. The red cells or corpuscles of the blood are about 1/3,000 of an inch in diameter. The largest cells when alone are barely visible to a person with good eyes. Cells work together.

Cells generally can do two types of work. One type of work keeps the cell alive, and includes using food and oxygen for an energy supply, growth, and getting rid of wastes. The other type of work is related to the work of the body as a whole. The cells of the bones deposit minerals. The nerve cells make electrical currents. The cells lining the mouth give off a fluid. Every other kind of cell also has some special function.

The cells of a given kind make up tissues, and tissues make up organs. Several organs taken to-

gether make up a system, and all the systems together make up the body. There are nine recognized systems of the body. The muscles and skeleton move the body, protect it, and give it shape. The systems which circulate materials—that is, take in and release air, digest food, and get rid of wastes—are primarily related to providing energy for body activities. The nervous and glandular systems control the body. The reproductive system functions only in adults and produces new life.

What is the body framework? The bones themselves do not do much work. Inside certain larger bones is a tissue called the marrow from which the red blood cells grow. But the bones have no power to move themselves, and require little energy. Most of the chemical material of bones is a mineral, calcium phosphate. Some bones, particularly the bones of children, contain a springy, tough material called cartilage. Some bones are more or less spongy, others are rock-like. Bones are covered with a sort of skin and have tubes and spaces inside them through which blood circulates.

Some bones, like those of the leg, are long and shaped like irregular cylinders. Flat bones are found in the skull and ribs and a few other places in the body. The backbones and some skull bones are irregular in shape. And there are short bones in the wrists and ankles.

The body framework or skeleton consists of the leg and arm bones, the neck bones, the skull, the backbone, the pelvis, and the ribs. Most of the larger muscles of the body are attached to these bones. They support the parts of the body and many of them serve as levers. Some of the bones act

The skeleton provides a framework for the body and protects some of body's important organs. How many parts of the skeleton can you name?

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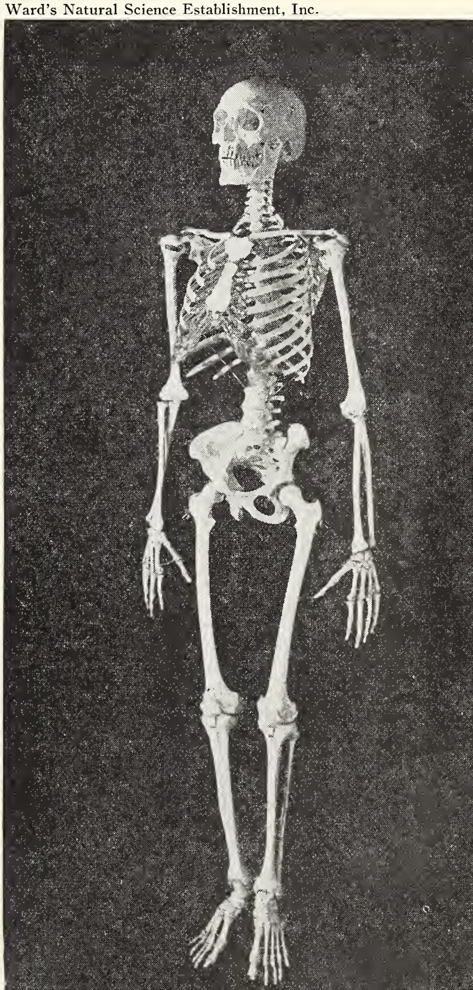
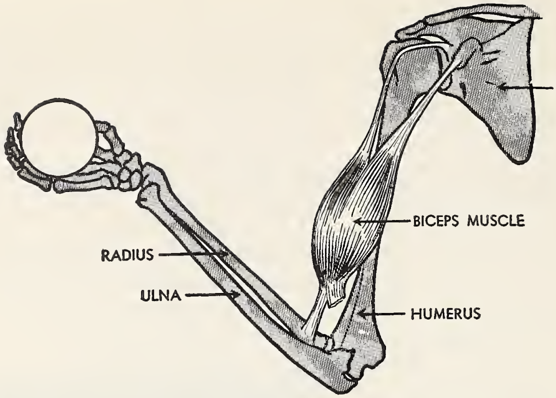




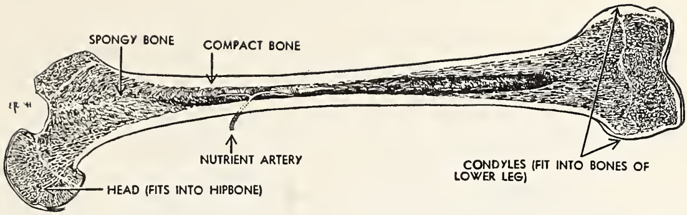
The biceps, the big muscle of the upper arm, is the motor which moves the forearm. Note how it is attached and how the bones of the arm fit together. Where are the ball-and-socket, the hinge, and the sliding joints?

as anchors for muscles rather than as levers.

The moveable bones are held together by cordlike tissues called ligaments. The bones are shaped so that they fit together well. The rounded end of one long bone usually fits into the hollowed end of the one next to it. Some of the bones of the skull lock together quite securely. The point at which bones meet is called a joint. Some joints are moveable. Those which are located in the knees, elbows, fingers, and toes are hinge joints. The shoulder and hip joints are ball-and-socket joints. In the wrists and ankles are sliding joints. There are also joints at which the bones do not move in the skull. These are called fixed joints.

Many of the organs of the body are fairly soft, and do not have enough firmness and strength to support themselves. The brain is contained in the skull and protected by it from most kinds of injury. The heart, lungs, liver, stomach, and several other organs are protected in part at least by the ribs. The pelvic bones provide some protection to the organs of the lower part of the body.

What do muscles do? The muscles do two chief kinds of work in the body. They produce motion and they release heat. There are two kinds of muscles. The muscles we control are called voluntary muscles, and are found in the arms, legs, hands, feet, and many parts of the trunk. The muscles which we cannot control are called involuntary muscles. They control such things as the size of the iris of the eye, the movement of food in the intestines, the emptying of glands, and the flow of blood. The voluntary muscles, when examined under the microscope, are made up of long bundles of fibers. Across



This big bone of the upper leg is strong. Inside the bone is the marrow in which red blood cells are manufactured. Note that a blood vessel enters the bone.

these bundles are stripes of a color slightly different from that of the rest of the muscle fiber. Involuntary muscles do not have these stripes.

The larger muscles of the body are attached to bones by tough bands or strips of material called tendons. Muscle cells can contract, or make themselves shorter. Tendon cells cannot do this. Muscles in the food tubes are arranged in circles somewhat like drawstrings. The food is pushed along by the muscle squeezing it. Muscles inside the eye are not attached to bones, but work against each other.

Muscles cannot push. They can only pull. As a result, if a body part is to function, it is necessary for the muscles to be in pairs or more complex arrangements to provide motion in two directions. The muscles of the arm can easily be felt. If you move your arm, wrist, and forearm you can locate the opposing muscles by feeling them contract. Twisting motions of the limbs and body are accomplished by muscles which wrap part way around a bone or part of the body.

Muscles provide much of the protection needed by more delicate tissues. The organs of the lower part of the body receive most of their protection from heavy muscles. Many large nerves and blood vessels are so located that they are protected by heavy muscles. The walls of the intestines, the eye, the stomach, the heart, and many other organs are chiefly made up of muscle.

The involuntary muscles contract more or less automatically in waves when conditions are right. The voluntary muscles do not contract unless stimulated by a small electric current from a nerve.

Muscles and other parts of the body are fastened to each other by a skinlike membrane called connective tissue. Muscles often have a skinlike covering made of this tissue, which serves to keep the muscles moist and to make them slippery enough to move against each other without much friction. Bruising muscles may injure this tissue and produce painful soreness.

Exercise

Complete these sentences:

The parts of the body in which the actual work of living is carried on are the —1—. A system is usually made up of several —2—. All

the bones together make up the —3—. The functions of bones are to serve as —4— in moving the body, and to —5— delicate tissues. Bones meet at —6—, and moveable bones are held together by —7—. Muscles in the legs and arms are —8—, while those of the heart and intestines are —9—. Muscles can move only when they —10—.

2. How is energy released in the body?

Most of the energy used in the body is released in the muscles. Muscles release 90 per cent of the energy used in the body, the remaining 10 per cent being released chiefly in glands. Glands make chemicals of various kinds used in the body. Almost all of this energy is given off in the form of heat, 80 per cent of which passes from the skin. Another 17½ per cent of this released heat passes from the lungs, and the remaining 2½ per cent is lost in wastes given off from the body.

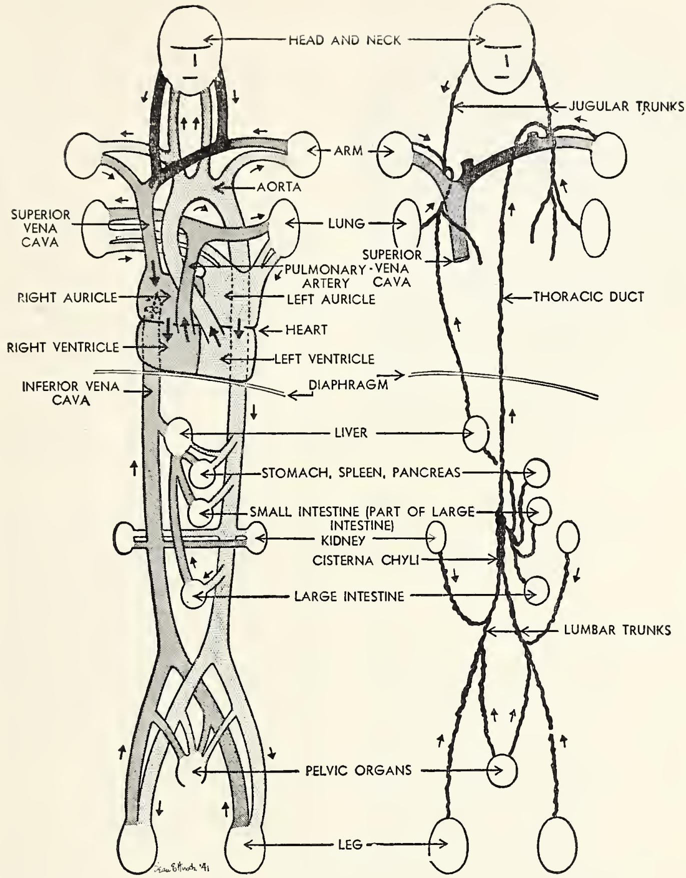
In order for the cells to release energy they must have a constant supply of food and other needed chemicals, plus a supply of oxygen. The body has special systems that provide these materials to the cells.

How does blood circulate? The circulatory system consists of the heart, which is a muscular pump; the arteries, through which blood is carried to the body; the capillaries, which carry blood among the cells; and the veins, through which blood returns to the heart. The liquid which passes to the cells from the blood vessels is called lymph. It is collected and returned to the heart through a series of tubes called the lymphatic system.

The heart has four chambers, two on each side. There are two intake chambers, called auricles, and two outlet chambers, called ventricles. The right side of the heart receives blood from the body and pumps it to the lungs; the left side receives blood from the lungs and pumps it to the body. The strongest muscles of the heart are in the left ventricle.

The blood is prevented from flowing backward through the heart and veins by muscular valves. These valves are flaps which form a V opening at the point and which are attached to the blood-carrying tubes along the sides. When pressure is exerted upon the blood enclosed in any part of the circulatory system, the valve on the side nearest the heart is closed, and the valve on the other side of the point of pressure is opened by the pressure. The valves of the heart are supported by muscular cords of fibers which keep them in place.

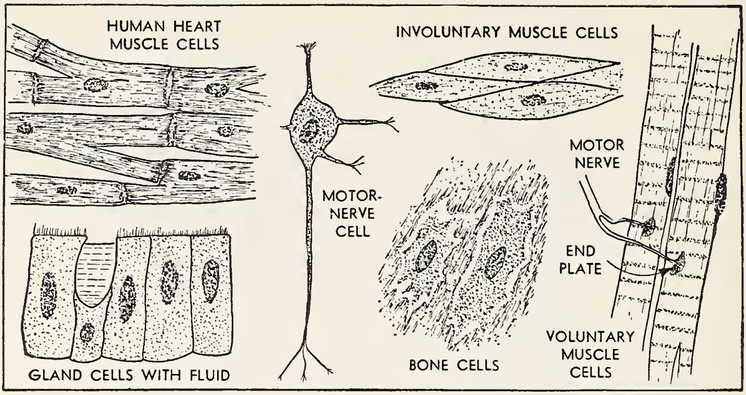
The pressure of the heart causes blood to flow to all parts of the body. It flows to the intestines where it absorbs food, to the cells where the energy of the food is released, to places in the body where food is used for growth or for storage, and to the kidneys, liver, and other organs



The diagram of the circulatory system (*left*) shows the four chambers of the heart and most of the important blood vessels. The blood vessels carrying oxygen are shown in a lighter tone. The lymphatic system (*right*) collects lymph from the cells and returns it to the superior vena cava, a big vein. The lymphatic system also collects food from the small intestine. The lacteal shown on page 230 empties into a tube leading to the cisterna chyli. Digested fats in particular are absorbed through the lymphatic system.

for getting rid of waste. The blood circulates completely every 2½ minutes.

Blood is a complex fluid, being both a suspension and a solution. The carrying fluid consists of salt and water. The blood includes two kinds of cells: the red corpuscles, which carry oxygen, and the white corpuscles, which are



Cells which perform different functions in the body are different in structure and size. Though some of these cells are magnified more than others, all are greatly enlarged.

the destroyers of bacteria in the body. The blood fluid carries dissolved food, soluble wastes, carbon dioxide, and chemicals necessary for the regulation of the body. The liquid of the blood washes every part of the body except the bones, teeth, and skin.

Because of the pressure within the circulatory system, the lymph must be forced along by greater pressure in order to return to the heart. This pressure is provided by the movement of muscles. It is this fact that explains the relief produced by exercising and rubbing sore muscles. The lymph tubes empty into a vein near the heart.

The heart beats about 120 times a minute in childhood and about 72 times a minute in adulthood. The heart does in a day 400,000 foot-pounds of work, which is equivalent to lifting 20 tons of coal 10 feet.

How is oxygen used in the body? Just as oxygen is essential for burning of fuel, so it is essential for the oxidation of food in the body. The human body, because of its size and because it requires much energy, has special equipment for providing oxygen. We cannot take in enough oxygen through our skins, as a worm can, or through simple tubes, as can the insects.

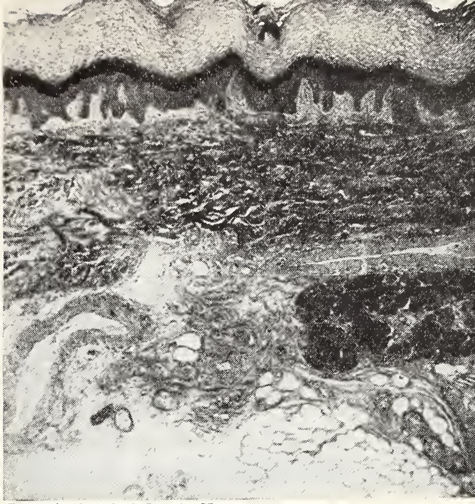
The lungs are made up of tiny sacs connected to the windpipe by a series of many-branching tubes. As the branching becomes finer and finer, the surface is increased. The capillaries wind and branch over 2000 square feet of surface, bringing the blood into contact with the air. To bring air into the lungs, two sets of muscles—those of the ribs and those of the diaphragm [dī′*ȧ*·frăm]—expand the chest cavity. The lungs are of soft tissue, having no muscular power of their own. Normal air pressure causes

air to flow into the lungs when the chest cavity is expanded. As the muscles of breathing relax, the chest cavity decreases in size, and air is forced from the lungs.

The rate of breathing depends upon age and upon the rate at which energy is used in the body. Babies breathe about 40 times a minute, and adults about 20 times. We breathe faster when we exercise. Each breath of an adult takes in about a pint of air, although by breathing deeply a man can take in more air than this. (See page 232.)

The change which takes place in the blood in the lungs is rather amazing. It enters the lungs loaded with carbon dioxide absorbed from the body cells and with the supply of oxygen in the red corpuscles quite well exhausted. Within a few seconds it gets rid of its carbon dioxide, and the red corpuscles take on a supply of oxygen sufficient to change the color of the blood from a dark, purplish-brown to a brilliant red. The chemical which brings about this change in color is an iron compound, hemoglobin [hē′mȯ·glō′bĭn]. This compound combines with oxygen readily in the lungs, and just as readily gives it up to the cells.

Blood which flows from the lungs to the body is bright red; that which flows from the body cells is dull red. The blood of the body arteries and the pulmonary [pŭl′mȯ·nĕr′ĭ, pertaining to the lungs] veins is bright red in color. Why?



General Biological Supply House

The human skin consists of the horny epidermis overlying the living dermis. Beneath are blood vessels, muscle tissues, and deposits of fat.

How is energy released in the cells? Every one of the numerous chemical changes in the body takes place in the cells. Most of these changes are complex and but poorly understood. The changes are more than the simple oxidation we observe in burning of fuel and rusting of metals. This oxidation takes place at low temperatures, for the body temperature is normally 98.6 degrees Fahrenheit. No flame or noticeable release of heat results from many of the chemical changes in the body.

The energy foods—fats and sugars—are ordinarily oxidized immediately as they are released for use. Some sugar is stored in the liver, and some fat is stored in the body beneath the skin and

around the muscles and intestines. Stored fat and sugar may be released into the blood stream as needed. The growth and repair foods provide the numerous chemicals required to regulate the body, to digest food, to rebuild protoplasm, and to form the teeth and skeleton. Some of these life processes are the result of chemical changes in certain highly specialized cells; while other processes, particularly the process of growth, are shared by all cells.

Exercise

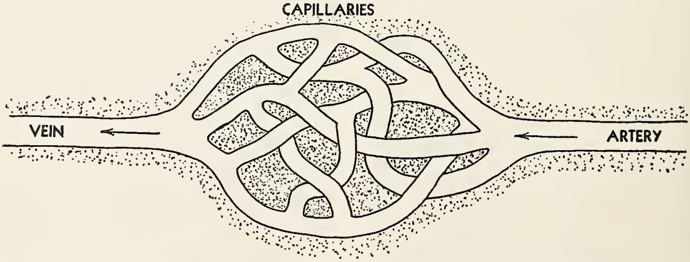
Complete these sentences:

The human heart has —1— chambers. Blood flows from the heart through the —2— and returns through the —3—. The blood plasma, or fluid, among the cells is called —4—. Arteries and veins are connected by —5—. White blood corpuscles combat —6—, while red corpuscles have the function of carrying —7—. A chemical called —8— carries the oxygen in the red cells. All energy in the body is released in the —9—. Energy is released as a result of —10—.

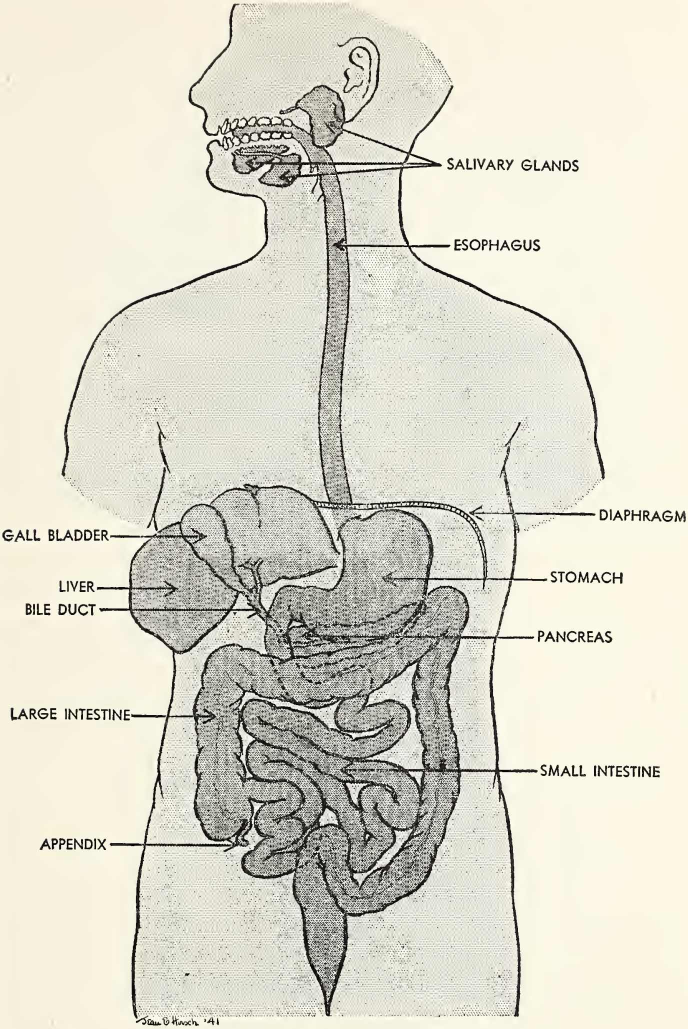
3. How is food digested?

Food is one of the two materials required for the release of energy in the body, and the chief material needed for growth. Foods as eaten are not usually useful to the body. They must be made soluble or broken into small particles which can be carried by the blood. Most foods must be changed chemically into forms which the cells can use. There are three general classes of food materials, the carbohydrates, the fats, and the proteins. Each of these foods requires different digestive action to make it useful.

What is the digestive system? Digestion is accomplished in a set of organs called the digestive system. The digestive system consists of the alimentary canal, which is a long tube extending entirely through the body, and other organs along the canal. These other organs produce various chemicals which act upon the food. Such chemical-producing organs are called glands. The alimentary canal consists of the



The capillaries are hairlike tubes which connect the arteries and veins. They wind in and out among the cells.



The chief organs of the digestive system are shown in this diagram. They are spread out somewhat in order to show each one. Only the pancreas is hidden behind other organs.

mouth, a food tube to the stomach, the stomach, the small intestine, and the large intestine. The large intestine really does very little work properly called digestion. The entire alimentary canal

in a grown-up person is from 25 to 30 feet in length, with the small intestine making up about 20 feet of the total. The large intestine is usually about five feet in length. The intestines are coiled and twisted inside the lower part of the body cavity. The words "small" and "large" refer to diameter, not length.

The glands which produce digestive juices are the salivary glands of the mouth, the gastric glands of the stomach, the liver, the intestinal glands of the small intestines, and the pancreas [păn′krė·ăs], which pours its fluid into the small intestine.

Where are foods digested? Most of the change of digestion is chemical, but in the mouth a very important physical change occurs, that is, the chewing and wetting of the food to bring chemicals into contact with it. The digestive juice in the mouth is saliva, which is secreted by three pairs of glands. These glands can be located by running the tongue around the inside of the lips and mouth. About three pints of saliva are secreted daily. Saliva acts on the starches changing some of them to sugar, as shown in the experiments of testing for sugar. There is not time enough for the saliva to digest much of the starch during the short time the food stays in the mouth. The work begun here is finished later by another juice in the small intestine.

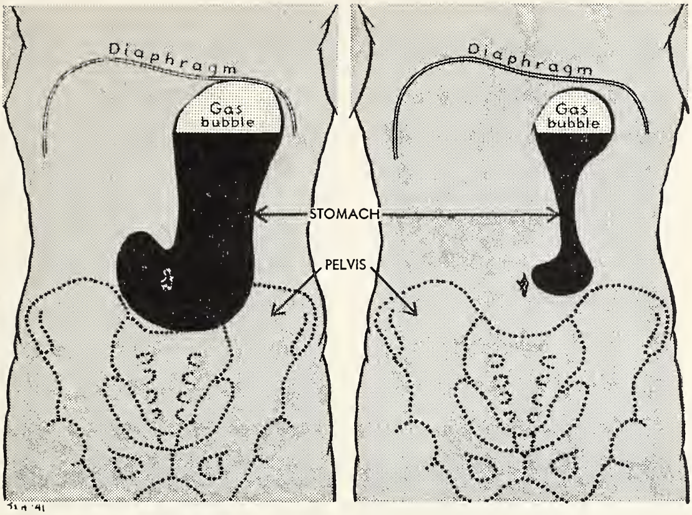
When food is swallowed, the little gate, or epiglottis, covers the windpipe and prevents food from getting into the lungs. The digestive and breathing tubes cross in the back of the mouth. Swallowing is a definite pushing along of the food by the muscles of the food tube.

The stomach is a pear-shaped pouch which, when full, is less than a foot long and five inches wide. It is capable of holding about two quarts. There are valves at each end of the stomach to regulate the movement of food. Contrary to the general idea, the stomach is not chiefly a digestive organ, but it is a storehouse which prepares the food for digestion later in the system. Food stays in the stomach ordinarily for two or three hours. During this time it is very slowly turned over and over, constantly becoming more liquid.

There is a difference in the length of time that various foods remain in the stomach. Fat and protein foods stay in the stomach about three hours on the average, while fruits and vegetables pass through the stomach in about two hours. The amount of time that food remains in the stomach differs with different people, this difference being as much as 30 minutes to an hour in some cases.

Food is acted on by two chemicals in the stomach: hydrochloric acid and the gastric juice. The acid neutralizes the saliva, which is alkaline (like a base). Every normal person has an acid stomach. The gastric juice starts the digestion of the proteins, changing them into simpler substances.

The opening leading from the



These drawings are made from X rays of the stomach when it is full and when it is empty. The stomach extends lower in the body than many people think. The bubble of gas is almost always present.

stomach to the small intestine is kept closed most of the time by means of a strong muscle band. Every little while this opens momentarily, thus allowing some of the food to pass from the stomach into the small intestine.

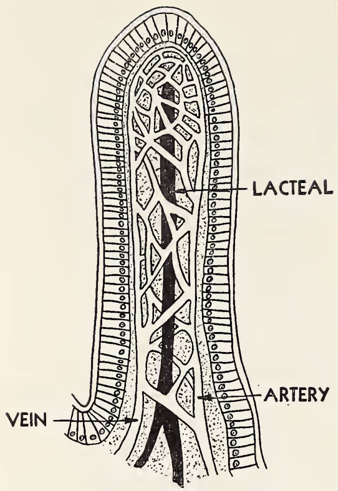
The small intestine is the chief digestive organ of the body. In it three juices act upon the food: the pancreatic juice, which comes from the pancreas; the intestinal juices, which come from glands in the walls of the intestine; and the bile, which comes from the liver. The bile is stored in the gall bladder.

The pancreatic juice is the most important digestive fluid. This juice is secreted or produced by the pancreas, which is located just below the stomach. It pours about a quart of digestive juices daily into the upper end of the small intestine. The pancreatic juice acts upon starches, fats, proteins, and sugars. In the upper third of the small intestine the bile begins its action upon fats. Since fats do not dissolve completely, the action of the bile is to form soaplike compounds which form emulsions in the digestive fluids.

In the lower two-thirds of the small intestine the intestinal juices complete the work of digesting whatever is left undigested.

In the large intestine bacteria and yeasts act upon indigestible waste materials which pass through the small intestine.

Most of the work of digestion is the result of action of chemicals called enzymes [ĕn′zīm]



This projection (greatly magnified) on the inner wall of the small intestine has the function of absorbing food. The lacteal is a lymph tube which carries fluids toward the heart.

found in the digestive juices. There are at least 10 different enzymes in the digestive juices, each with its own chemical activity to perform.

How is food absorbed? As the food is digested and passes through the alimentary canal, it is absorbed into the blood stream. From the stomach simple sugars and alcohol may be absorbed. In the upper third of the small intestine some quickly digested foods and soluble minerals and vitamins are absorbed. Most of the foods are absorbed in the lower part of the small intestine. The large intestine absorbs only water.

The small intestine has special folds and finger-like projections called villi, which dip into the digested food and provide a large surface through which food may be absorbed into the blood.

Dissolved foods are taken directly into the capillaries and become part of the blood. Inside the villi are tiny lymph tubes, called lacteals, which absorb the digested fats. By means of the lymph and blood, food is carried to the cells of the body.

The large intestine is a storehouse for wastes, and not chiefly a digestive organ. Near the beginning of the large intestine is the vermiform appendix, a little tube which now has no use, but which may cause trouble if irritated or inflamed. The disease caused by this condition is called appendicitis.

The movement of food is slower than most people realize. Food is passed in small amounts from the stomach to the intestine. In the small intestine it remains for five or more hours, and in the large intestine, 20 hours. Food normally may move even more slowly than this. In a normal person it may take indigestible substances two or more days to pass from the body. It is unwise to attempt to speed up this movement by taking medicine. Movement is caused by the slow and rhythmic [with regular motion] contraction of muscles located in the intestine walls.

Can we aid digestion? Although we have no direct control over digestion, we can influence it indirectly. We can eat desirable foods. Food is forced along through the intestines by

the action of their muscles. In order that this movement shall proceed easily, it is necessary that there should be in the food some indigestible materials. Therefore, we should eat some such bulky foods as fruits, vegetables, and whole-wheat bread. We can also control the time of our eating by having regular hours for eating. Food should be thoroughly chewed. When it is broken into fine particles, a better opportunity is given for the digestive juices to act. Furthermore, we enjoy food better if it is thoroughly chewed, and enjoyment of food aids digestion.

DEMONSTRATION: WHAT HAPPENS TO MILK IN THE STOMACH?

What to use: Milk, test tubes, burner, rennet liquid or junket tablet, vinegar or hydrochloric acid.

What to do: Warm gently a little milk in a test tube (do not boil) and add one-quarter teaspoonful of liquid rennet or one-eighth of a junket tablet. Set the mixture aside for a few minutes.

To one-quarter test tube of milk add dilute hydrochloric acid or vinegar and shake the tube.

What was observed: What was the effect of the rennet and the acid on the milk?

What was learned: What changes result from the action of the chemicals found in the digestive juices of the stomach?

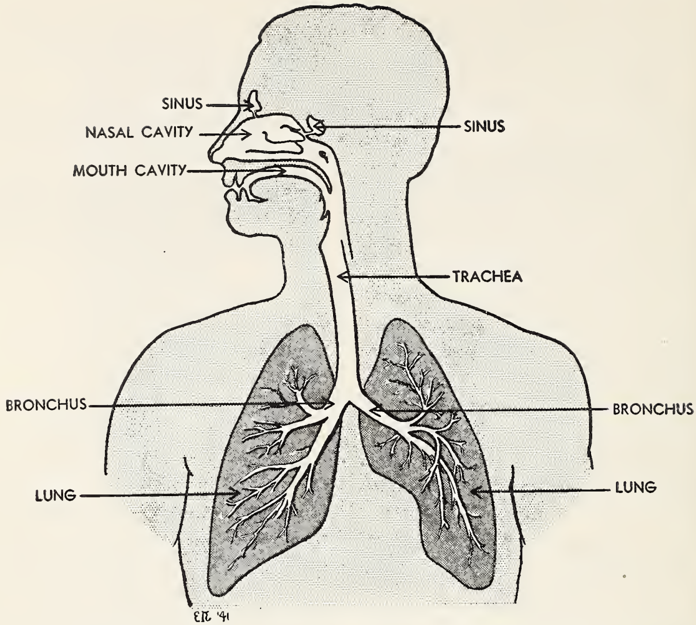
Exercise

Complete these sentences:

The result of digestion is to make food —1—. Starch, when mixed with saliva, is changed to —2—. Gastric juice is secreted in the —3—. Chewing and wetting food is a physical change necessary for —4—. —5— foods are broken down in the stomach. The gall bladder stores —6—. The most important part of the digestive system is the —7—. When —8— are digested, they become soaplike. Fats and proteins are made soluble in the —9—. —10— is the digestive juice secreted in the mouth. Bile aids in the digestion of —11—. The most important digestive juice is that secreted by the —12—.

4. How are wastes removed from the body?

It is estimated that the body is perhaps 20 to 25 per cent efficient in its use of energy available in foods taken into the body. It is therefore obvious that much of the food material taken into the body is never oxidized, but passes from the body in various stages of decomposition. From the foods that are completely oxidized, there are the products of oxidation, carbon dioxide, and water. Many of the food materials which enter the body are either indigestible or fail to be digested completely in passing through the mouth, stomach, and small intestines.



The air is warmed, cleaned, and moistened by the winding nose passages. It is distributed to the lungs by many branching tubes.

Thus there are three types of waste to be removed from the body: carbon dioxide and related gases formed by oxidation, the solid materials remaining in the large intestine, and the materials carried in solution in the blood from the cells. There are four organs active in removing these wastes: the lungs, the large intestine, the skin, and the kidneys.

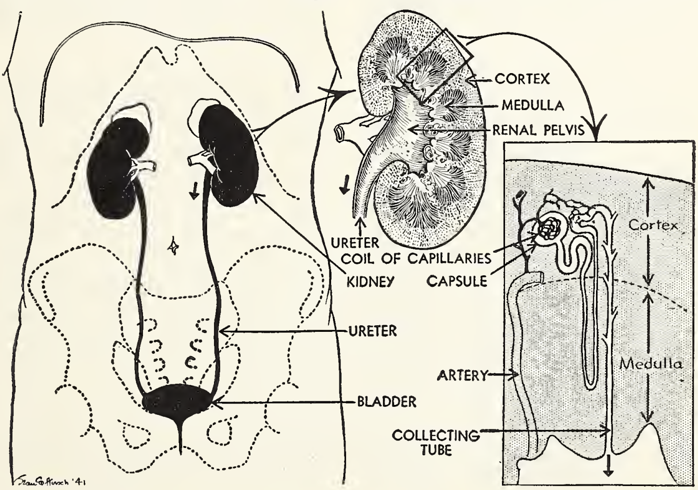
What is the work of the lungs? Waste gases are excreted chiefly through the lungs. The carbon dioxide is carried partly in solution in the blood and partly by the corpuscles. This gas escapes through the thin membranes of the lung sacs. The composition of air taken into the lungs and that passed out indicates the amount of change produced by oxidation of food.

	OXYGEN (PER CENT)	CARBON DIOXIDE (PER CENT)	NITROGEN, ETC. (PER CENT)
Air breathed in	20.96	.04	79
Air breathed out	17.00	4.00	79

It may be noted that the amount of oxygen in the air is decreased by about 20 per cent, which indicates that the proportion of oxygen absorbed in the process of breathing is rather small. The amount of carbon dioxide breathed out is 100 times the amount breathed into the lungs. The lungs also give off considerable amounts of water vapor.

Control of the processes of breathing is dependent in part upon the amount of carbon dioxide present in the air in the lungs. Pure oxygen is less readily absorbed than is oxygen containing a small proportion of carbon dioxide. Almost pure oxygen is used for breathing by airplane pilots and for treatment of certain illness.

What is the work of the large intestine? The wastes resulting from incomplete digestion of food consist of vegetable and meat fibers, skins of corn and beans, wheat bran, seeds, fruit fibers, and cell walls. Mixed into these wastes are enormous numbers of bacteria which produce enzymes which further break down the waste materials. At times these bacteria may make up half the weight of the waste mass in the large intestine. They are generally beneficial to the body in their action. Sometimes, of course, the large intestine contains disease bacteria or worms, which pass from the body into soil water supplies. A standard method of testing water is to count the number of intestinal bacteria found in it. Any purification process that does not remove most of the harmless bac-



The first drawing to the left shows the location of the kidneys and the bladder; the second shows a cross-section view of the kidney; and the third shows a greatly magnified view of the tubule which collects wastes from the blood.

teria may permit dangerous bacteria to escape into the drinking water supply.

The work of decomposition of food wastes in the large intestine is accomplished by enzymes produced by the bacteria, and not by any chemicals produced by the body itself.

One of the organs concerned with eliminating wastes from the body is the liver. It is closely netted with blood vessels which bring waste materials from the cells. The liver removes some of these wastes and returns them to the intestine. Much of the work of the liver, however, is to produce bile and to serve as a storehouse of sugar and certain vitamins.

What is the work of the kidneys? There are two kidneys, located beneath the lower ribs of the back. From each kidney a tube called the ureter extends to the bladder, which is located in the lower, front part of the abdomen. The function of the kidneys is to filter out of the blood three products: waste water, the products formed by destruction of protein in the cells, and salts, such as ammonia and table salt. Excretion of wastes is made possible by the action of the cells of the kidney tubules [tū′būlz].

Each kidney is made up of more than a million coiled tubes, the cells of which absorb the water and wastes from blood in the capillaries closely wrapped around each tubule. Every part of each capillary is closely wrapped with kidney cells. In both kidneys it is estimated that there are almost 300 miles of tubules. The total surface of the blood carriers exposed to the action of the kidneys amounts to about 70 square feet.

Each kidney produces a drop of urine in about 30 seconds. The urine flows down the ureter into the bladder, where it is stored until it is expelled from the body.

The amount of water which one drinks determines to a large extent the rate of production of urine. If more water is drunk than is needed by the body, the excess water is immediately excreted.

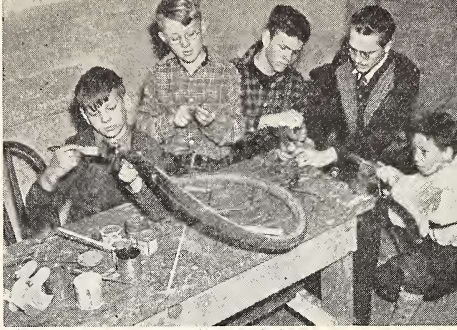
Does the skin excrete wastes? The skin is an excretory organ, for some waste products are carried from the body by perspiration. The materials carried in perspiration are water and salts. You can verify this by tasting the skin of your arm.

The skin also gets rid of waste heat. Two main methods of getting rid of heat are used. One is the method by which any body cools—giving off heat into the surrounding air by radiation.

The amount of heat radiated is controlled in part by the circulation of blood in capillaries under the skin. When the body is cool, little blood flows near the skin; but when it is warm, the capillaries enlarge and more blood flows through. The other method of regulating body temperature is by evaporation of perspiration. Perspiration is produced in the glands of the skin.

On the average, the body gives

off about two quarts of water every 24 hours through the sweat glands. The amount varies, of course, depending upon the temperature of the surrounding air and the activity in which a person is engaged. Vigorous exercise causes free flow of perspiration. The evaporation of the extra perspiration removes the heat freed in the muscles when they become more active. In this case, the heat is waste heat, and must be removed in order to keep body temperature normal. A nice balance is maintained between the heat produced in the body and the amount of heat lost.



Minneapolis Board of Park Commissioners

The many complex acts which we take for granted depend upon the control of healthy bodies guided by complex nervous systems. How many kinds of skills are these boy craftsmen employing in their work?

Exercise

Complete these sentences:

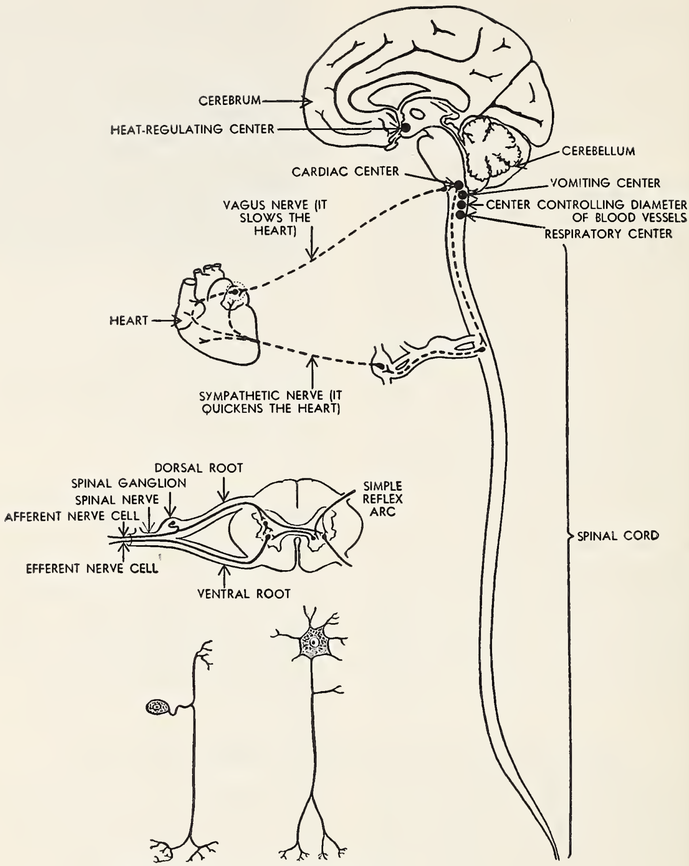
Products of oxidation are —1— and —2—. The lungs give off body —3— and —4—. Materials given off by the large intestine include —5— parts of food, materials given off by the —6—, and —7—, which act upon the wastes. The kidneys excrete waste —8—, broken-down —9—, and —10—. The kidney consists of many tiny —11— which closely surround the —12— which bring wastes from the cells.

5. How is the body controlled?

To a certain extent every organ of the body controls our behavior in some way. The structure of our bodies determines what we can do. We walk upright partly because of the kind of legs and feet we have. Our hands are the most adaptable organs possessed by any animal. We can do such greatly differing operations as threading a needle, operating a typewriter, holding a baseball bat, shuffling cards, and chinning ourselves because our hands are so flexible, strong, and well co-ordinated.

But there are other special organs which control, co-ordinate, and stimulate the activities of all other parts of the body. These consist of the nervous system, the special sense organs, and the ductless glands.

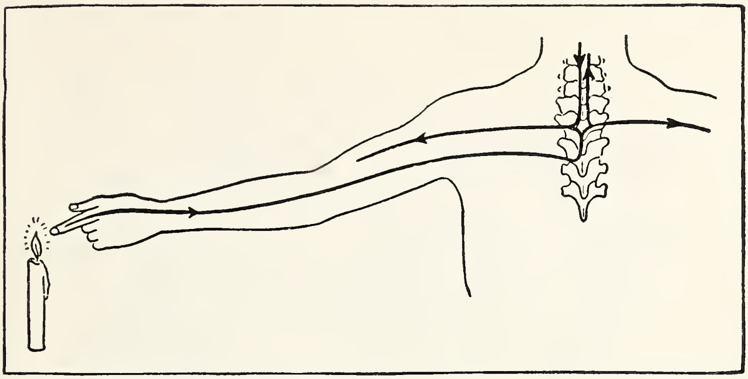
What is the nervous system? You know already that the central nervous system consists of the brain, the spinal cord, and the nerves which branch from it. The brain is divided into three parts. The cerebrum [sĕr′ē·brŭm] or forebrain is the largest part. The area of its surface is enlarged by ridges, which give the brain a roughened appear-



Locate the organs of the central nervous system. The black circles represent regions which control certain reflex acts. Connected to the spinal cord is shown part of the autonomic nervous system which controls the heart. The reflex arc shows the connection of nerves which control reflexes which are "short circuited" at the spinal cord. The sensory nerve cell carries sensations, while the motor nerve cell controls the response.

ance. The cerebrum is covered on the outside with a layer of gray matter, while the inside is made up of a network of millions of white nerve fibers. The cerebrum is the center of thinking and voluntary action. It also receives the stimuli from the special sense organs.

The cerebellum [sĕr′ė·bĕl′ŭm] is located under the back part of the cerebrum. This part of the brain is concerned with co-ordination of muscles which operate



Many sensations are carried only to the spinal cord before some action is produced.

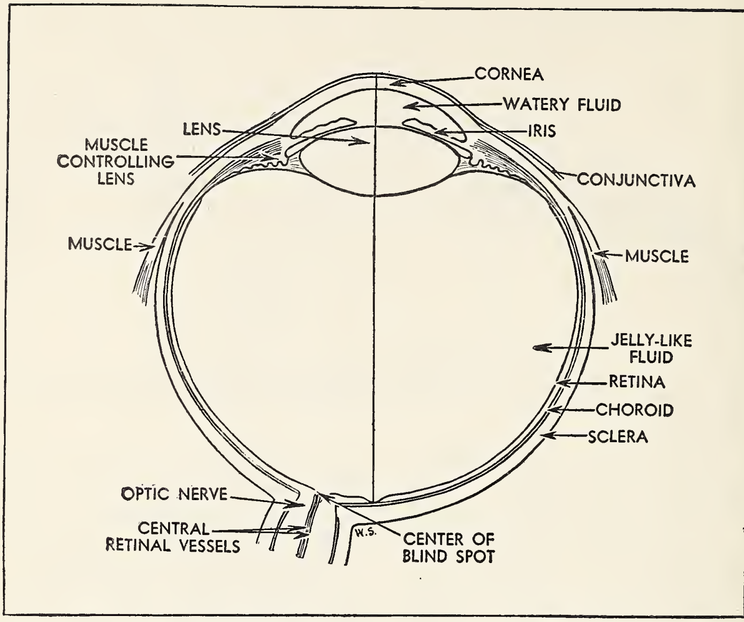
on the habit level. Walking, maintaining an upright position, and other acts of which we are not aware are controlled by the cerebellum. The medulla is the part of the brain which connects to the spinal cord. It controls breathing, circulation, and some of the reflexes.

The spinal cord connects the brain to the rest of the body, and carries nerve currents both ways. It also includes certain nerve centers, or ganglia, which control reflex acts. The short-circuiting of the reflexes through the spinal cord permits quicker responses than would be possible otherwise. This is an important matter in escaping danger. We can jerk the hand away very quickly when we are in pain.

There is another group of nerves and ganglia located in the chest cavity and abdomen. This system is not entirely separate from the central nervous system, for the two are connected by nerves. It controls many important involuntary actions, such as flow of digestive juices, excretion of wastes, movements of foods along the intestines, secretion of chemicals by the ductless glands, and other kinds of work which are essential to the simplest existence.

What are the special sense organs? You are already familiar with the operation of the eye and ear. The sense of smell, as you know, is dependent upon organs located in the nose. The sense of smell of man is not well developed, and we rarely attempt to train it to any useful purpose. The organs of taste are the taste buds located on the tongue. We have four senses of taste, for we can taste salty, bitter, sweet, or sour materials. All other senses which we call "tastes" are really odors. Apples, onions, and potatoes actually taste very much alike, as you may have discovered if you have ever lost your sense of smell because of a cold.

We have more than one sense



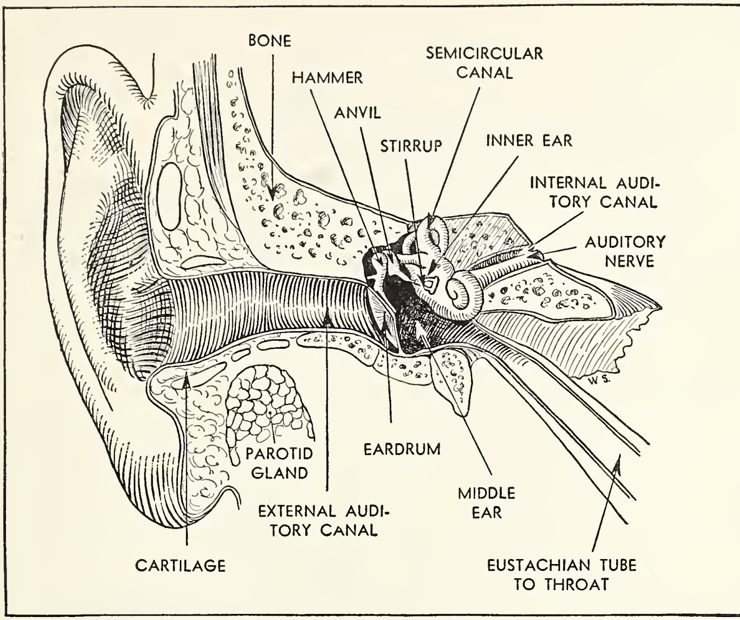
The eye and ear are highly developed special sense organs. Study the parts of the eye and explain the functions.

of touch. We can feel heat, cold, pressure, and pain. Most of the touch sensations originate in the skin.

A sensation is a nerve current set up by a stimulus acting on one of the sense organs. The nerve current, which is electrical in nature, stimulates other nerves in turn, until the sensation is carried to the spinal cord or brain. Sensations from the special sense organs give us our only means of learning about our surroundings and are our only real source of experience.

What is a response? A response is the behavior brought about by a reaction to a stimulus. It may be a movement of muscles or a flow of chemicals or a nerve current in the brain. We may respond strongly inwardly without showing outward evidence of it. For example, your heart may beat faster at the thought of an exciting game you played, but you do not move otherwise.

What causes our emotions? Have you ever been so upset that your mouth became dry, your knees shook, your breath came faster than usual, and you could not control your actions? If you have, you were affected by chemicals released in your blood by the adrenal gland, which in turn was stimulated by the nerves of the brain and autonomic nervous system. The chemical produced



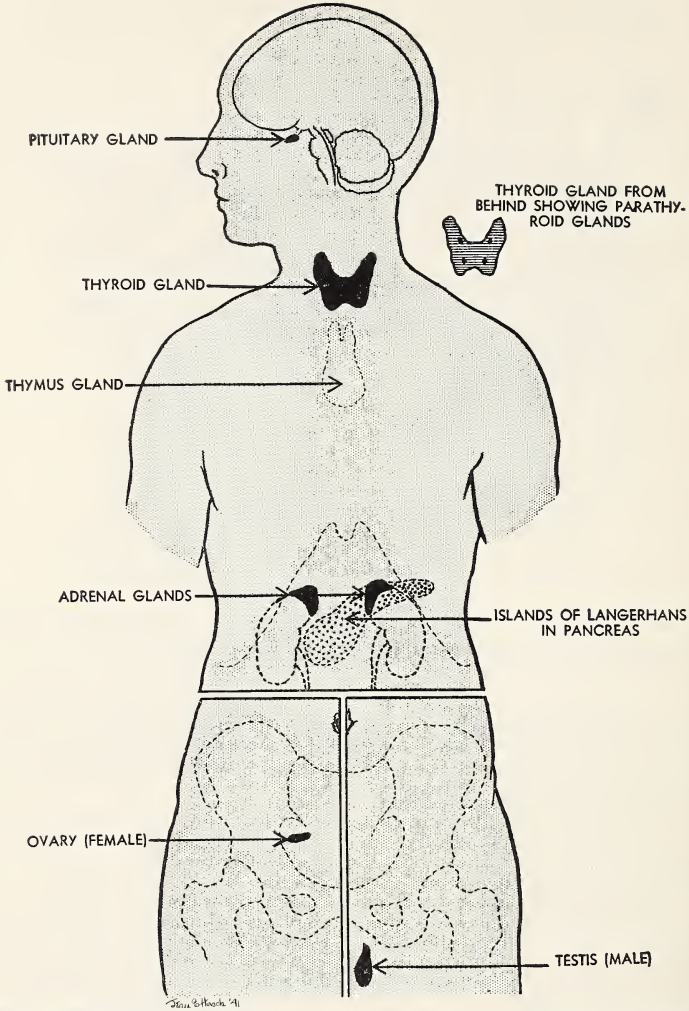
Study the parts of the ear and tell what each part does.

by this gland is carried in the blood stream and causes the release of sugar from the liver. It increases the speed of clotting of blood, as well as the more familiar symptoms of excitement. This emotional condition was useful to primitive man in combat or flight, but it is of little use to us today.

If we get emotionally upset in a civilized world, we have indigestion, lose friends, and conduct ourselves in unreasonable ways. If we control our emotions, we do not let our bodies get out of control. Controlled emotions make for friendly rivalry in sports and in doing worth-while work. Emotions are the basis for founding homes, for caring for others, and for keeping our self-respect. All these desirable things are dependent upon control of certain glands which operate automatically to cause upsets if once allowed to start action.

Other glands contribute to control of behavior to some extent. Too much thyroid secretion causes irritability and overactivity. Too little causes lack of normal mental development and makes the victim inactive and sluggish.

What are the common types of behavior? Like other animals, we have reflexes, instincts, and intelligence. Reflexes are such simple, unlearned acts as the control



The ductless glands, shown in black, produce chemicals which affect most of the acts of the body. The thymus is shown as a dotted line because it practically disappears when a person becomes an adult. The pancreas itself is not a ductless gland, but the islands of Langerhans are ductless. These regulate use of sugar in the body.

of the size of the pupil of the eye, the jerking of the knee, swallowing, and sneezing. One does not need to learn to act by reflex, for the pattern of behavior is already present in the nervous system.

Our instincts are more complex than reflexes and are also unlearned. They include such acts as sucking, striking out in anger, and struggling to escape if held against one's will. Instincts are not suitable types of behavior for civilized living, for man cannot get food, make love, and fight as animals do. We must learn to act as our social group acts.

Because we are intelligent, we can learn. Intelligence is the ability to change behavior in such a way that we find solutions to our problems to bring satisfaction to ourselves. Learning is a method of changing behavior.

When we meet a new problem, we may go about learning a solution in one of many ways. One of the most common ways of learning is by trial and error. That is, we keep on trying, and as we make errors, we try to avoid acts which do not bring desired results. We may solve some simple problems successfully in this way, but we rarely learn effectively by trial and error. Another method of learning is by imitation. That is, we see someone who has a satisfactory response worked out, and try to do the same thing. Much of our effective learning is a combination of trial and error and imitation. It is not natural to eat with a fork. A child first learns to eat with a spoon, missing his mouth as often as he hits it. Finally this complex skill is mastered, and a fork is substituted. Food falls from the fork, for it is harder to handle a fork than a spoon. But by setting an adult standard as a goal, the child finally learns, not only to keep food on the fork till it reaches the mouth, but also to do this work with a fair degree of grace.

The most complex form of learning is reasoning. In this method of solving problems, no physical activity is apparent. In fact if the correct solution is reasoned out, the first act of the muscles accomplishes the correct result. This type of activity is very useful for solving problems, but not so useful for learning such skills as typing.

We do not learn until we feel some emotional need for learning. We may have a personal need for a solution of a problem; we may want to make a good impression on others; or we may want to beat a rival. We may have a feeling of dissatisfaction with ourselves that is eased on by accomplishing something difficult. Whatever emotional drive we have, this drive makes learning easier and more certain.

Learning seems to depend upon certain nerve pathways existing in the brain and spinal cord. When nerve currents flow through a pathway that gives emotionally satisfying results, that pathway seems easiest to use again. We can learn so well that the response becomes a habit. Learning is not possible until the nervous system and body are mature enough to accomplish the desired result. A two-year-old child cannot throw a ball well,

no matter how earnestly he may try.

Exercise

Complete these sentences:

The —1— is the largest part of the brain and controls —2— acts. The —3— is the part of the brain which controls breathing. The —4— connects the brain with the rest of the body. Sensations are responses to —5— and are carried by —6— cells. Blinking of the eye is a —7— act. —8— behavior is complex and unlearned. A strong urge to action caused by chemicals produced in the —9— is called an —10—. —11— behavior makes finding solutions to new problems possible, and is the basis of —12—.

6. How do we grow?

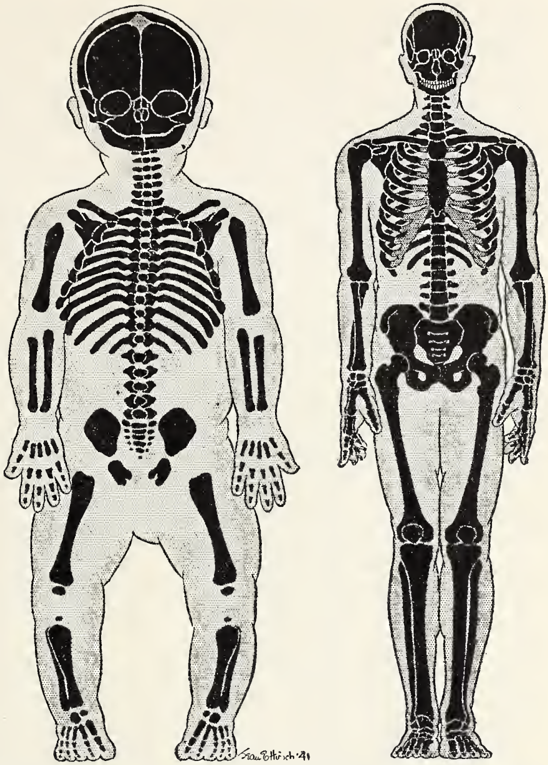
The use of food in the body satisfies three basic needs of life: energy, growth, and repair. The matter of growth and repair are essentially the same process, for repair of tissue results from growth of new cells.

Just what is growth? As you know, every living organism begins life as one cell. Any change in the organism, either in size or in complexity of parts, is growth. It is rather obvious that a gain in weight is the result of growth. The appearance of a beard where there was none before is also a matter of growth.

At the time of birth, the average person is quite well along the road to becoming a full-grown individual, for the average baby weighs about seven pounds. This weight amounts to about 6 per cent of final adult weight for girls and somewhat less than 5 per cent of adult weight of boys. All the food that was used by the baby in its development previous to birth was absorbed from the food supply of the mother. There is probably no more important factor in proper growth than a good start insured by an adequate diet for the mother. The usual processes of growth are measured from birth, but they do not start there.

What are the stages of growth? For the sake of convenience, growth is divided into four stages. During infancy, which lasts about two years, the baby is helpless and unable to care for itself in even the simplest things. This is a period of rapid growth, slowing down somewhat during the second year. Childhood extends from the age of 2 to the age of 12 to 15 for most boys and girls. In this stage growth is somewhat slower and is concerned with both increase in size and improvement of co-ordination of the parts of the body.

The period of adolescence is the age during which boys and girls become men and women. It begins at about 13 for the average girl and more than a year later for the average boy, although it may start for some individuals as early as 9 or as late as 16. Just before adolescence, and during the first years of this period, growth is unusually rapid. During adolescence girls



Scammon, Graca, and Noback

When the body of a baby is shown equal in size to that of an adult, it looks rather queer. Its head is large and its legs are short. Its bones contain little mineral and are soft and springy. The black lines represent bone mineral.

develop the appearance and organs of women. The boys become men. Their voices change and a beard appears. The most important factor in growth during this period is the maturing of the reproductive organs.

During the final period of growth, adulthood, changes take place very slowly. There is some increase in the size of the bones of the face and some slight increase in the amount of muscular development. Any marked increase in size during this stage is more likely to be due to adding fat than to adding to bone and organic weight. Physical adulthood begins for girls at about 16 to 18 and for boys at 20 to 22.

During the first 13 years of their lives, the average boy and girl are about the same size. During the fourteenth year, the average girl is larger than the average boy; but during the next year, the boy becomes larger and continues gaining until adulthood, when the average man weighs about 30 pounds more than the average woman. Yet in proportion to their final size, boys are behind girls even at the age of 20. The illustration on page 245

shows the relative completeness of growth in weight. The average girl has half her adult weight before she is 11, but a boy is more than 12 years old before he passes his halfway mark in growth. The average girl at 16 has only 5 pounds increase in weight to attain, while the average 16-year-old boy will increase about 25 pounds in weight.

What foods are essential for growth? A 14-year-old girl or boy needs about 24 calories of energy per pound of weight. A food calorie is 1000 small calories. But a year-old baby needs almost twice as many—about 44 calories. An adult past the age of 30 needs only 15 to 18 calories per pound, while an old man or woman needs only 11 calories per pound per day. From these figures it may be seen that the process of growth is one which requires energy and materials for building.

But provision of energy is not enough. The protoplasm [prō′·tô·plăz'm] of which the body is constructed is a complex chemical. You can remember some of the more important elements in protoplasm by fitting the names of the elements into the following "signboard": *C. Hopkins Cafe.* The C stands for carbon, the H for hydrogen, the Ca for calcium, the Fe for iron. Fill in the other elements between by referring to chapter 1. If you eat at this "Cafe" you will still be short copper, zinc, magnesium, sodium, and some other trace elements.

To enable the body to use its food, it is necessary to have the necessary vitamins which regulate growth and repair.

One nutrition expert estimates that to obtain an adequate diet every child out of the milk, orange juice, cod-liver oil, gruel stage should have *at least* the amounts of food in the following table:

Milk—one quart daily

Fruits and vegetables—at least three servings daily, including one raw green vegetable, two cooked vegetables besides potatoes, and orange or tomato juice.

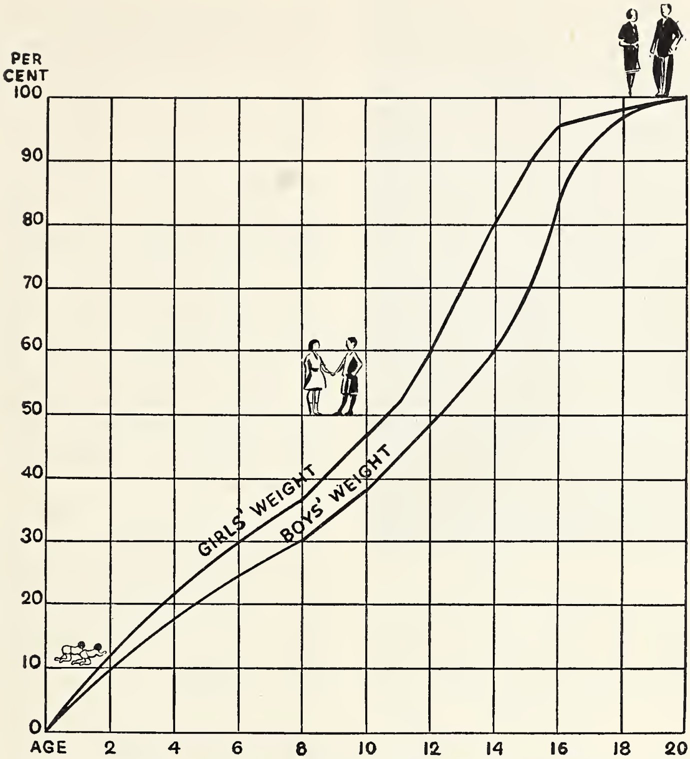
Proteins—two servings daily of egg, meat, fish, or cheese.

Cereals or bread—whole wheat bread or cereal

Fats—butter at each meal

To this minimum diet should be added potatoes, white bread, fat from meat or vegetables, a little sugar, and other foods of the type needed to supply energy.

What are the body regulators of growth? The controls which cause the changes in rate of growth of various parts of the body operate in a complex manner. Perhaps the most important of these controls or regulators of growth are the ductless glands. These glands, as the name indicates, have no ducts or tubes to lead their chemicals into certain parts of the body but, instead, discharge them directly into the blood stream. They form an interconnected system—that is, one gland may regulate a second,



This chart shows what per cent of growth is complete at different ages for boys and girls. For example, a girl is 30 per cent grown at six, while a boy is not 30 per cent grown until he is eight.

which in turn regulates some process of growth.

The pituitary gland certainly regulates growth of bones, and probably affects muscle tone. The thyroid gland has some influence on proper growth of bones and muscles, as well as upon mental ability. The thymus gland seems to be the one which prevents full maturing of the body until growth is nearly complete, for it almost disappears at the beginning of adolescence. The glands which produce the reproductive cells—the testes and the ovaries—each produce the chemicals required to bring about the bodily differences existing in men and women. The adrenal glands also regulate growth, in co-ordination with the pituitary and reproductive glands. There are other glands in the body which regulate growth to greater or lesser degrees. Much remains to be learned about the controls of growth.

The growth of the body is not uniform, either in the relation of the parts to each other or in relation to rate of change in size. During adolescence these differences in rate of growth may be rather embarrassing, for if the bones grow faster than the muscles can develop to control them, a temporary awkwardness may result. A girl may find to her alarm that her hips seem to be growing rapidly wider, while no other part of her body seems inclined to keep up with them. The feet may become adult while the rest of the body is not. These difficulties are not likely to last long and are unimportant if they do not cause worry.

Because of the sudden spurts in growth that sometimes occur, the amount of food needed may almost double for a few months.

The best way to check adequacy of diet is to have an occasional medical examination. If weight is normal or slightly above for build, age, and height, and if the child or adolescent has abundant vitality, nutrition is probably normal. The undernourished child is either underweight, or pudgy and inactive. The underweight child is often restless, overactive, and not inclined to sleep well. The pudgy, soft, undernourished child may be getting enough calories but not enough growth-regulating foods and therefore does not develop muscle or use energy at a normal rate.

Exercise

Write a summary of this problem, using in it the following words: birthweight, calories, childhood. adult, adolescence, protoplasm, adequate diet, ductless glands, vitamins.

7. What foods supply energy?

The amount of food you need is determined not only by your rate of growth, but also by how active you are and how large you are. As you become more active you may need much more than the 24 calories per pound normally required by persons 14 years old. A small person becomes cool faster than does a large person because he has more skin in proportion to his weight. Thus just to keep warm in cold weather a baby needs more food, in proportion to its weight, than an adult does. The best simple measure of how much food you need is shown by your weight and general condition. If you continue to grow at a normal rate, and are firm and healthy, you probably are getting enough food.

What are the classes of food? There are two kinds of foods or nutrients [nū′trĭ·ĕnt] in our diets: those which we use in considerable amounts and those which we require in small amounts. Three classes of foods that we need in large quantities —the carbohydrates, the fats, and the proteins—are the nutrients which are digested and used up

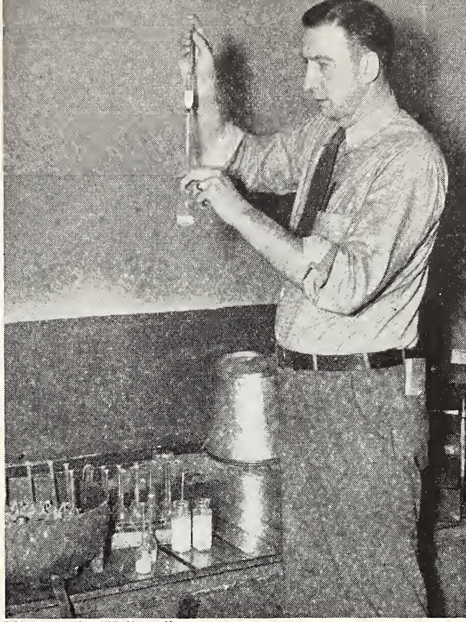
in the cells to provide energy and materials for growth.

The carbohydrates are the sugars and starches. All chemicals in this group are closely related because they are made up of carbon, hydrogen, and oxygen in slightly differing proportions. The starch we eat becomes sugar when it is digested. Among the sugars are the simple sugars, such as corn, milk, and grape sugars, and the double sugars, of which cane and beet sugar are examples. Soon after digestion begins, the double sugars are converted into simple sugars. Sugars are easily detected by their taste.

We find starch in many common foods—in potatoes, bread, cake, gravy, beans and peas, apples, and tapioca.

Because the carbohydrate foods are relatively cheap and in general pleasant to eat, the diet of the average person is made up in a large part of these nutrients. Carbohydrates are chiefly of value in the body for supplying energy.

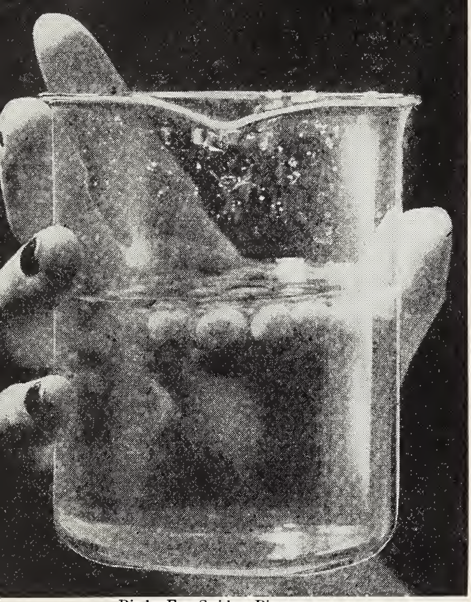
Fats include such common materials as butter, salad oils, fat meat, nut oils, and cooking fats. They are chemical compounds of carbon, hydrogen, and oxygen but differ from the carbohydrates in their molecular structures. The carbohydrates may be converted into fat in the body—that is, if you eat more sugar than you need, it will be stored in your body as fat instead of sugar. A certain amount of fat in the diet is needed to enable the body to use other foods, as well as to supply a concentrated energy food. There are at least two fat chemicals essential for health which the body cannot manufacture for itself. Fat is stored in the body and also serves as padding. Undernourished, lean people are irritable and nervous. Their nerves and bodies do not have enough padding for comfort.



Minneapolis "Tribune"

The amount of energy in milk is dependent in part upon the butterfat content. Here milk is being measured into test bottles. The bottles are then rotated in a machine to separate fat and milk.

Proteins differ from the other nutrients chemically in that they contain nitrogen, in addition to the three elements found in carbohydrates and fat. The protein foods are absolutely essential for growing children and for general



Birds Eye-Snider Pictures

In overmature peas, the sugar has changed to starch, which has a greater specific gravity than sugar. These heavy peas sink to the bottom, leaving the sweet and tender peas at the top of the brine solution.

health. Experiments indicate that meat eaters are healthier than vegetarians.

Protein in the diet is essential to maintain life. There are many different kinds of proteins, which differ in their value to the body. The proteins found in milk, meat, eggs, and cheese are more complete and of more value to the body than are the incomplete proteins found in beans, peas, wheat, and gelatin.

The chemical compounds of which proteins are made are called amino acids. Twenty-one such chemicals are known, and most or all of them seem to provide some material needed for the body. The complete proteins contain a larger assortment of essential amino acids than do the incomplete proteins.

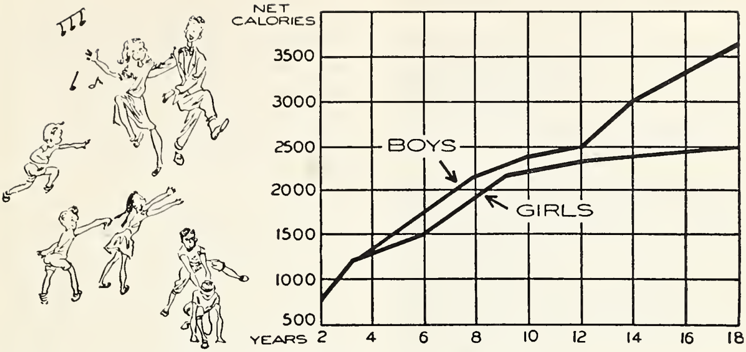
The proteins are perhaps as pleasant to eat as any other type of food. They are more expensive than carbohydrates or the cheaper fats, however.

How much energy do different foods supply? Fats are the best of all foods for providing energy. They have practically no other use in the body, except that some contain vitamins. A pound of pure fat supplies more than 4200 calories; a pound of protein or carbohydrate when dry contains less than 2000 calories. To get the right proportion of energy from the various foods, it is estimated that at least 15 per cent of the needed calories should be provided by protein foods, with the remaining 85 per cent equally divided between fats and carbohydrates.

The number of calories in an ordinary serving of food is shown for a number of common foods in the following list.

PROTEIN FOODS

	Calories
Milk, 1 cup	150
Egg, 1	70
Buttermilk, 1 cup	80
Cheese, cream and Swiss, 1 oz.	125
Cheese, cottage, 1 cup	250
Beefsteak, 1/4 lb.	240
Beef stew, 1 cup	300
Frankfurter, 1	135
Pork chops, 1/4 lb.	320



Based on: Human Nutrition (No. 1668 Yearbook Separate—1939.)
Continental Baking Company, Bakers of Wonder Bread

The average needs of boys and girls for food increase with age. Of course the needs of individuals vary according to their weights and activities.

Ham, 1/6 lb.	200
Salmon, canned, 1 cup	200
Chicken, young, 1/4 lb.	125
Creamed codfish, 1 cup	200
Halibut, 1/4 lb.	135
Bologna, 1/8 lb.	125
Roast beef, 1/8 lb.	120

CARBOHYDRATE FOODS

Oatmeal, cooked, 1 cup	120
Rice, cooked, 1 cup	135
Corn and wheat flakes, serving	75
Cracker, soda, 1	25
Bread, large slice	100
Doughnut, 1	150
Biscuit, cream, 1	200
Cake, av. helping	200
Potato, sweet, 1 av.	200
Potato, 1 av.	100
Cup custard, 1	250
Ice cream, vanilla, 1 cup	360
Jelly, large serving	100
Pie, mince, etc. av. serving	375
Pie, fruit, av. serving	350
Candy, 1 lb.	1400–2800
Sugar, 1 tbsp.	60
Baked beans, 1 cup	400

FAT FOODS

Peanuts, 35 (1 oz.)	280
Mayonnaise, 1 tbsp.	100
French dressing, 1 tbsp.	70
Cream, 1 tbsp.	25
Cocoa, 1 cup	225
Fats and oils, 1 tbsp.	110

FRUITS AND VEGETABLES

Apple sauce, 1 cup	200
Apricots, canned, 1 cup	180
Orange juice, 1 cup	100
Orange, 1 av.	80
Apple, raw, 1 large	100
Stewed fruits, 1 cup	100–150
Banana, 1 av.	100
Date, 1 av.	25
Grapes, raw, 1 cup	150
Cabbage, boiled, 1 cup	80
Beans, string, 1 cup	90
Carrots, 1 cup	80
Cauliflower, 1 cup	70
Lettuce, 1 serving	5
Asparagus, 1 cup	20
Spinach, 1 cup	40
Radish, 1 av.	10
Beets, 1 cup	80

MISCELLANEOUS

Soup, tomato, 1 cup	75
Soup, bean, 1 cup	250
Consomme, 1 cup	30
Pickles, 1 av.	10
Sandwich, ham, 1	300
Sandwich, fried egg, 1	350
Sandwich, tomato, 1	220
Gravy, brown, 1 tbsp.	15

It takes only a small amount of butter, but a large amount of tomatoes, to supply 100 calories. In general, the more fat a food contains, the higher its fuel value. The more water a food contains, the less its fuel value. Rich sources of energy are cereals, dried seeds, butter, cheese, and meats.

You can make an approximate estimate of the amount of food energy you need by multiplying your weight by 24. If you are active you will need more than the number of calories obtained by this calculation. To estimate whether or not you are eating as much as you need of the right kinds of foods, you can keep a food list and check it against the table containing energy values of foods.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: QUANTITY, KIND OF FOOD, CALORIES PER QUANTITY, NO. OF CALORIES. 1) *To estimate how much energy you get from your food, make a complete list of your foods for a 24-hour period. Include candy bars, ice cream, and all between-meal foods, as well as your regular meals.*

2) *Under* QUANTITY *try to estimate foods in cupfuls, tablespoonfuls, or average servings, as indicated in the lists on pages 248–249. Why will your results be inaccurate?*

3) *Complete the table and find the total number of calories consumed.*

8. Why are vitamins needed by the body?

Vitamins perform an unusual work, for they show their importance most in their absence. A person who eats a complete diet —that is, one supplying all the necessary foods—may never need to know anything about vitamins at all, for a complete diet is protection against diseases caused by lack of vitamins. Lacking a complete diet, one may develop eye disease, crooked bones, strange illnesses, loosening of the teeth, or paralysis, depending upon what type of foods are lacking in the diet. The vitamins, which by their presence prevent these difficulties, are substances found in certain foods.

The first definite discoveries about vitamins were made about 1910. Since that time a number of vitamins have been found. They have been named after the letters of the alphabet, A, B, C, etc. They also have difficult chemical names. Their characteristics have been learned by the effect their presence or absence has on the growth of animals.

U. S. Bureau of Home Economics

The rat at the top had a normal diet. The second rat lacked vitamin A. The third rat lacked B_1 and suffers paralysis. The guinea pig lacked vitamin C and has scurvy and sore joints. The two rats with crooked legs and short bodies lacked vitamin D. The last rat, which is losing its hair, lacked vitamin G, which is one of the vitamin B group.

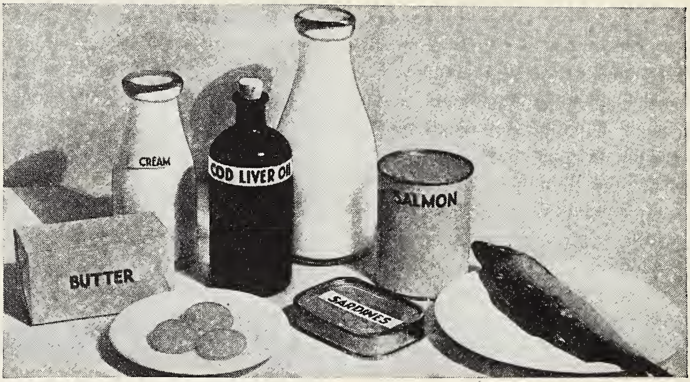
To test the effects of vitamins, two groups of white rats are generally used. One group is given a diet deficient in vitamins, while the second group is given enough vitamins for a normal diet. Of course people cannot be used like rats in experiments, yet observations that have been made of the food habits of sick people indicate that the effect of vitamins on people is similar to that on rats.

Vitamins may also be tested by laboratory methods. Since most of the vitamins have now been separated into pure chemicals, their properties can be determined. Vitamin B_1, C, and D are white solids, the first two soluble in water.

What is vitamin A? Vitamin A promotes growth and general body health. Lack of vitamin A produces eye and skin diseases. People who can see well in the daytime but are blind in dim light at night usually recover from the night blindness if given vitamin A. A diet rich in vitamin A is particularly important for those who drive much at night.

Vitamin A is found in many common foods, some of the best sources being eggs, butter, cream cheese, carrots, green vegetables, and fruits. The more green or yellow color a food contains, the more likely it is to contain materials from which the body makes vitamin A. The green outer leaves of lettuce contain 30 times as much vitamin A as do the pale inner leaves. Cod-liver oil is also rich in vitamin A.

What is the complex vitamin B group? What was formerly called vitamin B is now known to be made of twelve or more vita-



U. S. Bureau of Home Economics

These foods contain vitamin D; but since there are so few foods that contain this vitamin it is particularly important for boys and girls to play in the sunshine, as the sun's rays furnish the body with vitamin D. It is not necessary, however, to obtain a deep tan.

mins, including B_1 (also called thiamine) and B_2 (also called riboflavin) and niacin. Lack of B_1 may cause the disease known as beriberi, common in the Far East. Paralysis, loss of weight, soreness of the muscles, and general illness are symptoms of the disease. Lack of B_1 also causes loss of appetite. Users of alcohol in large amounts usually do not eat foods containing vitamin B_1. This vitamin is abundant in the coverings of grains, the part that is removed from the whole kernels when making white flour and by polishing rice. The vitamin is abundant in whole wheat flour and rough rice. It is also found in fruits, green vegetables, pork, milk, eggs, liver, yeast, and nuts. B_1 is perhaps the most essential of all vitamin foods.

Lack of one or more of the vitamin B group is the cause of the disease pellagra. This disease is quite common among the poorer people who live on the corn bread-bacon-molasses diet. The disease may show itself in eruptions on the skin and in disturbances of the digestive and nervous systems. It can be prevented by including in the diet eggs, meat, milk, and a variety of fresh fruits and vegetables, all of which contain vitamins of the B group. It may be cured by use of brewer yeast tablets.

What is vitamin C? Vitamin C is known to prevent scurvy, a very unpleasant and dangerous disease which causes loosening of the teeth and changes in the gums. This vitamin helps to form and maintain the teeth and bones properly. Oranges and tomatoes are the best sources of this vitamin, although it is found in most fresh fruits and green vegetables. A half cup of orange juice, or a cup of tomato juice supplies the

smallest safe amount of vitamin C for one day's needs for a 120-pound person. Potatoes contribute an important amount of vitamin C to the average diet.

There is good evidence that in very young children the most important factors in growth of strong teeth are sufficient vitamins, especially C and D, and minerals.

What is vitamin D? Absence of vitamin D causes rickets, a disease of the bones. Bowlegs, crooked feet, uneven growth of ribs, knock-knees, crooked teeth, and poor growth of all the bones of the body result from lack of vitamin D. Vitamin D also speeds up the growth of broken and injured bones.

Vitamin D may be supplied to the body in two ways. The body can make the vitamin when exposed to the ultraviolet rays of the sun. It is therefore called the sunshine vitamin. The vitamin can also be supplied in our foods, but it is not as abundant as are the other vitamins. The largest amounts of this vitamin are found in the oil extracted from the livers of certain fish, such as cod, shark, and halibut. Among our foods the best sources of vitamin D are milk, fish, liver, eggs, and butter.

Experiments have shown that by feeding cod-liver oil to cows the amount of vitamins D and A found in the milk fat was greatly increased. Vitamin D can also be supplied to milk by letting it run through a beam of strong ultraviolet light.

What are other vitamins? Vitamin E affects the ability to reproduce. It is an important part of the royal jelly fed to queen bees to keep up their ability to produce eggs. It is found in many foods, and there is little evidence that it is normally lacking in human diets. Vitamin K controls the normal clotting of the blood.

How does cooking affect vitamins? The effect of cooking is not the same on all vitamins. Vitamin C is the most sensitive and is more easily destroyed than are the other vitamins. Cooking cabbage destroys nearly 90 per cent of the vitamin C present in fresh cabbage. However, canned tomatoes contain almost as much vitamin C as the fresh tomatoes. The reason this vitamin is not destroyed in canning seems to be that the tomatoes are exposed to the air for only a short time while they are being heated. Mashing potatoes reduces their vitamin C content. Apple sauce contains almost no vitamin C. Fresh fruits and vegetables contain a large amount of vitamin C. The drying of fruits and vegetables destroys much of this vitamin.

Vitamins A, B_1, and B_2 are not greatly affected by the heat used in ordinary cooking. The use of soda to soften cooking water destroys vitamins B_1 and B_2. Vegetables should be cooked by dropping them into boiling water which is free of oxygen. The water should be boiling vigorously when leafy vegetables are dropped into it in order to save as much vitamin C as possible.

U.S.D.A.

Fresh vegetables contain all the vitamins except D. Most of the vitamin B found in potatoes is in the skin. Canning vegetables may destroy vitamin C, if they are exposed to air in cooking.

Are vitamins important in the normal diet? People who have little money to spend upon food too often try to omit from the diet the foods containing vitamins, especially fruits, milk, eggs, meat, and green vegetables. Then too, many children are so badly trained in thier food habits that they do not care to eat these foods and, as a result, remain sickly and underweight. They are more likely to fall victim to diseases than are other children. Cooks too often throw away the colored leaves of lettuce and cabbage and save the less valuable inner leaves.

A person may eat enough calories and still starve to death. A variety of foods containing vitamins is essential for health. Because vitamins have certain values in the diet, quacks who sell foods, medicines, and cosmetics are quick to take advantage of public ignorance concerning their true use. Vitamins are advertised as being essential parts of cosmetics, cold creams, health foods, patent medicines, and many other materials in which they are not naturally found. But vitamins have little value except in foods, or in medicines prescribed by a doctor.

DEMONSTRATION: CAN WE TEST FOR VITAMINS?

What to use: Vitamin A and C capsules or cod-liver oil and orange juice; antimony trichloride; carbon tetrachloride; 2,6 dichlorophenol indo-phenol; test tubes; medicine dropper; forceps.

What to do: Dissolve the contents of the vitamin A capsule or several drops of cod-liver oil in about 15 milliliters of carbon tetrachloride. Drop a

crystal of antimony trichloride into the solution. (*Warning*: Handle antimony trichloride only with forceps.) If the crystal turns violet in color, vitamin A is present.

Dissolve 50 milligrams of 2,6 dichlorophenol indophenol in 100 milliliters of water (or 1 gram in 2 liters of water). Put the vitamin C in a very little water in a test tube. Drop by drop put the test solution into the vitamin C solution. If the color disappears vitamin C is present.

What was observed: Describe what happened.

What was learned: What are tests for two vitamins?

Exercise

Complete these sentences:

Vitamin C prevents —1—. Vitamin —2— gives resistance to skin disease. Vitamin B_1 prevents —3—. Vitamin —4— is the only one that can be made by the body. Vitamin —5— prevents pellagra. Vitamin D prevents —6—. Vitamin —7— is known as the sunshine vitamin. —8— are animals most commonly used in experiments with vitamins. The vitamin most easily destroyed by cooking is —9—.

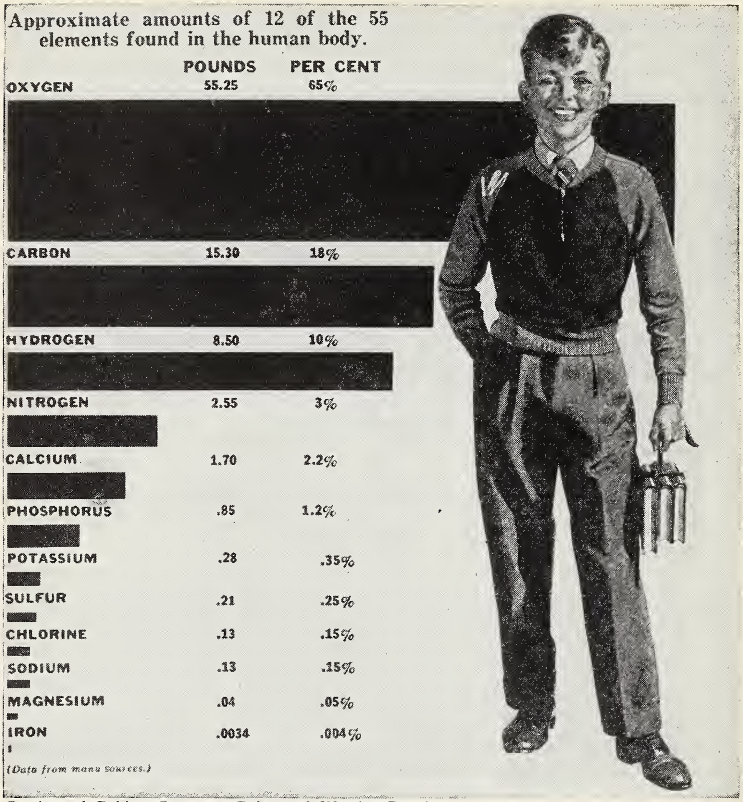
9. What minerals are needed in the diet?

Minerals are needed in the body for two purposes. They constitute the major portion of the bones and teeth and also are essential in small amounts for providing chemicals needed for growth of the cells. These minerals must be taken into the body in foods, for in their pure state practically none of them are useful. Some are actually poisonous if taken in concentrated form.

Why do we need calcium? Calcium, the element found in lime, is the mineral used most abundantly in the body. The chemical of which bones and teeth are chiefly composed is calcium phosphate. Every person needs calcium, but it is especially important for children and for mothers during the time their babies are developing. Calcium cannot be used in the body unless there is also present an adequate amount of vitamin D. Lack of sufficient lime in the diet causes poorly formed teeth, rickets, tooth decay, and in extreme cases convulsions and loss of bodily control.

The best source of calcium in the diet is milk, for it is easy for most people to use large amounts of milk. Buttermilk and cheese also supply calcium. Other good sources of calcium are the green leafy vegetables—cabbage, broccoli, chard, mustard and turnip greens. There is some calcium in most vegetables.

Why do we need phosphorus? Phosphorus is usually used in the body combination with calcium, although phosphorus is also needed for the growth of cells. Although more phosphorus than calcium is used up in the body daily in the processes of living, it is easier to get enough phospho-



Continental Baking Company, Bakers of Wonder Bread

This chart indicates the amounts of some of the chemical elements which make up the body of the 85-pound boy.

rus than enough calcium. The foods which contain calcium also contain phosphorus. In addition, beans, lean meats, peas, eggs, soybeans, most nuts, and most fish contain phosphorus.

Why do we need iron? The chief uses of iron are to form the red chemical in the blood cells and to provide iron for the growth of body cells. Each day about a trillion new blood cells are formed in the body, and each needs its tiny portion of iron. An inadequate supply of iron or improper usage of iron in the body results in a disease called anemia [*ȧ*·nē′mĭ·*ȧ*]. The disease results in lack of vigor, paleness, and low resistance to infectious diseases. Sometimes anemia may be fatal.

Lean meat, egg yolks, leafy vegetables, liver, and beans are good sources of iron. Whole grains and

a few fruits contain useful amounts of iron. Milk contains so little iron that it is of no value in providing iron in the diet.

What other minerals are needed? Copper is essential for proper growth, but it is required in such small amounts and found in such a variety of foods that it is likely to be present in sufficient amounts in any normal diet.

Iodine in the diet is essential for regulating the growth of children and the use of energy in the bodies of adults. Iodine is used in the body by the thyroid gland, a spongy organ situated in front of the windpipe. Lack of iodine or improper use of iodine in the body causes goiter, a disease of the thyroid gland. Upsets of this gland may make a person nervous and irritable, or inactive and fat.

Iodine is found in foods grown near the sea but hardly at all in foods grown inland. Sea foods are the best source of iodine. In most regions far removed from the ocean a small amount of an iodine compound is added to table salt.

Certain elements, needed by the body in such small amounts that it is difficult to determine just how much is needed, are found in traces in the human body. Among these elements are manganese, which is related to bone growth and reproduction; cobalt, which is related to production of red corpuscles; magnesium, which is related to growth; and bromine, which is concentrated in a gland within the skull.

U. S. Soil Conservation Service

Erosion may remove from the soil so many soluble minerals that people of the region may be undernourished from lack of proper mineral foods.

How much mineral do we need? The body contains enough calcium for about seven pounds of lime, enough phosphorus to make about two pounds, enough sodium to make a shaker of salt, enough iodine to make a tenth of a drop of tincture of iodine. The rest of the minerals are found in amounts too small for common measures. Yet in terms of diet these are large amounts, for the amounts found in food

are also mere traces. It is necessary for a child to drink about 100 gallons of milk a year to get as much calcium as he needs.

How can we cook foods to save minerals? Most of the minerals found in foods are soluble in water. If the food is boiled in a large amount of water for a long time and the water is then thrown away, most of these minerals may be lost. The correct cooking method, of course, is to use as little water as possible, cooking the vegetables partly in steam in a closed kettle. Vegetables should be cooked only until they are tender. If meat is to be cooked with green vegetables, the meat should be almost entirely cooked before vegetables are added. Vegetables cooked with roasts of meat usually retain their minerals. In any event, the water should be served with the vegetables and eaten. Excess water may be used to add to gravy.

Are there poisonous minerals? There are a number of elements which even in small amounts are poisonous. Among these are mercury, arsenic, lead, selenium, and copper. Mercury may be inhaled from vapors from broken lamps and thermometers or from any other source of liquid mercury. Lead and arsenic are most commonly taken into the body by eating food contaminated by Paris green and arsenate of lead sprays.

Selenium is found in the soil of certain dry regions just east of the Rocky Mountains. Cattle in these regions sometimes die from eating vegetation grown in poisoned soil. It may be necessary to abandon such soils for production of food. There is no way by which you can know whether or not flour you buy came from wheat grown in these areas.

Copper is sometimes introduced into food by contamination from cooking containers, but rarely in dangerous amounts.

How can we conserve soil minerals? Since soil is used to support dense populations for generation after generation and since minerals are dissolved from the soil by water, each year there is less and less mineral left in the soil to enrich plant food. People living in regions where the soil is poorest live upon the products of that soil because they can afford no other food. They often lack so many necessary foods that a shortage of minerals is probably not the only cause of their lack of vitality. Yet it is entirely probable that food from better soil would lead to improved health of many individuals in these depleted regions.

Scientific agriculture rebuilds soil as it is used. This is the only way to insure an adequate supply of minerals in our diets in the future.

DEMONSTRATION: WHAT FOODS CONTAIN MINERALS?

What to use: Bunsen burner; crucible; ring stand; beans, wheat, or cocoa; loop of iron or platinum wire; a calcium compound; milk or milk curd.

What to do: At the beginning of the period put about a teaspoonful of

one of the foods in the crucible, and heat it as hot as possible until nothing is left but a white ash.

For a control, heat a little of a calcium salt, held on a wire loop, in the flame, and observe the deep orange color produced by calcium vapor. Be sure that your wire loop is clean, and repeat the test with milk or milk curd. (Some city water will produce this color also. Keep equipment clean.)

What was observed: How much ash did the food contain?

What was learned: Does food contain mineral? Do you know what minerals are found in the ash? What is the test for calcium?

U.S.D.A. Extension Service

The protein food produced by pole beans requires nitrogen from the soil for its formation.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: MINERAL, FOUND IN, USE IN BODY, HARM RESULTING FROM ABSENCE. *Fill out the table by writing into the columns the names of minerals mentioned in this problem, a few foods containing them, and other information.*

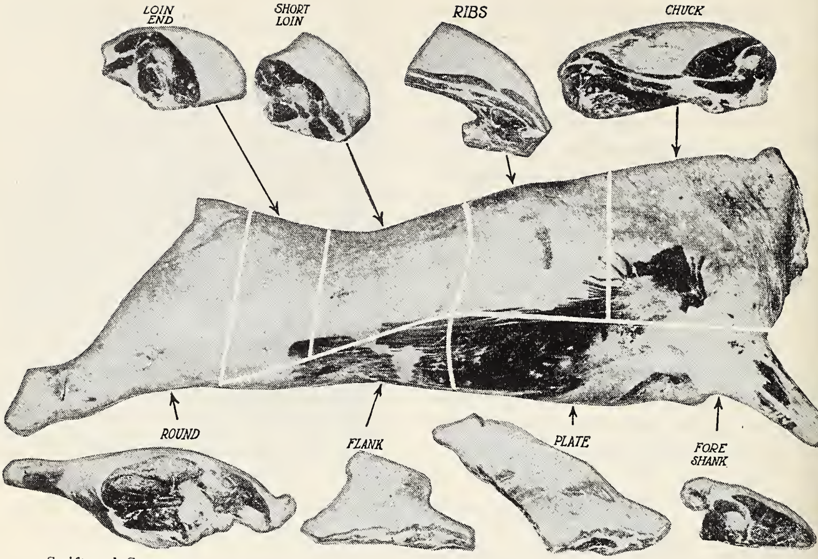
10. What is a balanced diet?

A balanced or complete diet is one which has the correct amounts of all types of foods needed to maintain good health and proper weight and to provide energy for activity. Food scientists have tested hundreds of kinds of foods to determine their value in the body, both as sources of energy and as building materials for growth.

It is not easy for the individual to know whether his diet is balanced or not. Most people have certain food habits which they have built up as a result of family preferences and availability of foods on the market. Advertising of certain foods overemphasizes their value, when in fact they may be of almost no importance in the total diet. In the past, before real scientific studies of food values were made, several quite impressive books were written about diet, and much of the information they contained has since proved to be wrong.

How is value of food tested? The unscientific observer is likely to decide what foods should be included in his diet on grounds of taste, early training, or other unsound reasons.

Scientific testing of foods is an exceedingly difficult matter. Yet



Swift and Company

Cuts of meat are sold at different prices. The cut that sells for the highest price is tender and of good flavor. Another cut may have as much protein and sell at a lower price.

today our knowledge of foods is quite complete. The use of the white rat in these food tests has made it possible for people to test diets which no human subject would consent to try, for many diets thus tested are so unsatisfactory that they result in permanent injury to the animal.

The usual procedure is to select two groups of rats equal to each other in number, weight, sex, age, and inheritance. To one group a certain diet is fed, while the other group receives a diet exactly the same as that given to the first group, except that one experimental food is either added or left out. In this way, differences in weight, appearance, rate of growth, number of young produced, and other indications of vitality can be judged accurately. Sometimes, for the sake of checking the experiment, the experimental food is added to the diet of the less healthy group of rats to see if they can be improved in condition by use of the test food.

It is not entirely possible to conclude that any diet that is good for rats will be equally beneficial to human beings. Yet the similarities between the food requirements of rats and of men are much more numerous than are the differences. Even where differences seem to exist, the rat experiments at least open the

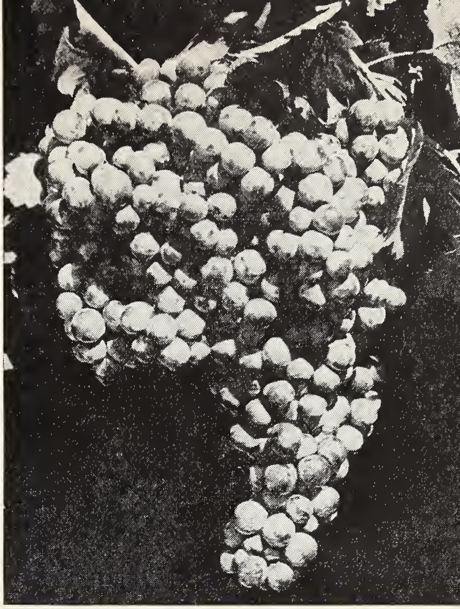
way for experiments with diets for human beings.

Another type of food testing is complex chemistry. To discover the exact proportions of various food nutrients in the common foods is a task that only a college-trained scientist can perform. There are many positions open in industry and in the government bureaus for food chemists.

The table below shows the nutrient content of a few of the common foods, as determined by chemical analysis [study of a material by breaking it into its parts].

Can you obtain a balanced diet? You cannot carry around testing equipment and balances to measure the various foods you eat to be sure that they contain all the foods you need. You can, however, follow two rules which will assist greatly in choosing needed foods. The first is: *Eat a large variety of foods of each of the different food classes every day.* The second is: *Whenever possible eat the less refined foods instead of the more refined foods.*

Breakfast is an especially important meal. After a long night without food, the actual energy supply of the body is low. A per-



Grapes and all fruits contain carbohydrates, but they also contain needed minerals and vitamins.

son who is hungry has less endurance and becomes tired and irritable rather easily. People who are hungry in the morning tend to look tired and unattractive. A good breakfast supplies needed energy. Moreover, foods commonly eaten for breakfast contain many essential nutrients, including vitamins and minerals. Fresh fruit or tomato juice, an

FOODS	FAT (PER CENT)	CARBOHYDRATE (PER CENT)	PROTEIN (PER CENT)	MINERALS (PER CENT)	WATER (PER CENT)
Apple	0.5	14.2	0.4	0.3	84.6
Banana	0.6	22.0	1.3	0.8	75.3
Beef sirloin	19.1	0.0	19.0	1.0	61.3
Bread (white)	1.3	53.1	9.2	1.1	35.3
Egg	10.5	0.0	14.8	1.0	73.7
Milk	4.0	5.0	3.3	0.7	87.0
Potato (white)	0.1	18.4	2.2	1.0	78.3

egg, whole wheat cereal or toast, and a glass of milk will supply real building materials for a healthy body. It is possible to eat a poor breakfast, consisting of coffee, dry white toast, and jam, but even this poor breakfast is better than none.

A lunch can also provide needed foods. Milk; fruit; and sandwiches containing meat, cheese, eggs, or peanut butter provide both calories and building foods. If vegetables can be added, so much the better. Pop, candy bars, and cake are of little value in body building.

Every dinner should be built around a protein food and this food should be, whenever possible, a lean meat. Beans or peas, nuts, cheese, fish, and eggs may be substituted in turn, but should never replace meat completely. Vegetables and fruit, raw or cooked, should always be part of a dinner. Butter or enriched margarine should be used at every meal.

Overrefined foods have several faults. They are usually soft and lack roughage which encourages thorough chewing and good digestion. They usually have lost most of their vitamins and minerals by too much treatment. They generally are mostly starch and sugar, which are of value for energy but which are lacking in essential body-building nutrients. Sugars are particularly likely to be used in too great quantity. Sugar is responsible for some tooth decay. It is part of a great many foods, pops, ice cream, and most sweet desserts.

Do people need special diets? Probably two-thirds of all people can and should eat almost any kind of foods which are good and readily available, so long as a balance is maintained. A few people need special diets. A person who is really overweight needs a reduction of the number of calories, with no reduction of mineral, protein, or vitamin intake. A reducing diet is very low in sugar and fats, and fairly low in starch. No diet containing less than 1200 calories a day is considered to be safe even for a short time.

A person who is greatly underweight needs a careful study of his diet before attempting to gain weight. Lack of vitamins in the diet, particularly one of the B vitamins, may cause lack of appetite. Lack of other vitamins or minerals may make it difficult for the underweight person to absorb his food. Most underweight is caused by eating too little of all kinds of food or by too much activity.

People who drink alcohol excessively depend upon the alcohol to provide energy, and often have starvation diseases because they do not take into their bodies enough vitamins, minerals, and proteins.

Some people have food allergies. They are poisoned by foods most people can eat. Allergies show themselves in skin eruptions, in sneezing and cold symptoms, in nervousness, headaches, and intestinal upsets. An allergy

can be caused by almost any food, but chocolate, strawberries, cucumbers, milk, whole wheat, or tomatoes are often found to be responsible. You will not need to give up eating these foods unless a doctor directs you to, however. A person who has a food allergy must substitute other foods for those which cause illness.

DEMONSTRATION: HOW DO WE TEST FOODS?

What to use: Iodine, nitric acid, Fehling solution or Benedict's solution, ammonia, burner, ring stand, test tubes, foods, oil, corn meal, paper, metal disk.

What to do: Test for starch. Prepare a thin paste by heating a little starch or white flour in water. Add to it two drops of iodine solution. Note the deep-blue, almost black, color.

Test for sugar. Use either Fehling solution or Benedict's solution. To one-eighth of a test tube of a thin corn sirup add about a teaspoonful of Fehling or Benedict's solution, and heat until the mixture becomes a deep orange-red in color. Test rolled oats. Chew some rolled oats for some time, and test. Has chewing made a difference in the oats?

Test for protein. Place a small amount of egg white or milk in the test tube and add about one-sixth of a tube of nitric acid. Bring it to a boil. Carefully pour off the acid, cool the tube, and add one-eighth test tube of ammonia [ammonium hydroxide]. The color should be first yellow, then orange.

Test for fat. Place ground-up corn or commercial corn meal upon a piece of paper, and place the paper upon the metal disk on the ring stand. Heat the metal very gently with the burner. After several minutes examine the paper for "grease spots" made by the corn meal.

What was observed: Make a table of the tests, including the name of the food, the purpose of the test, the chemicals used, and the changes observed.

What was learned: Summarize your observations.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: fat, protein, carbohydrate, cane sugar, grape sugar, starch, amino acid, iodine, Fehling solution, ammonia, nitric acid.

A review of the chapter

The human body is a complex organism which is adapted to use the energy of foods to carry on the various life processes. The chief systems of the body are the skeleton, the muscles, the digestive system, the excretory system, the circulatory system, the respiratory system, and the nervous system. Each of these parts of the body uses energy in performing its functions.

Food provides the body with energy. Proteins provide food for growth and repair, and carbohydrates and fats provide a source of energy. Vitamins and minerals regulate body functioning, growth, and repair. Food is oxidized in the

cells to which it is carried by the blood. Food wastes are removed through the kidneys, lungs, intestines, and skin. A balanced diet is necessary for health, and a correct intake of calories is essential for maintaining correct weight.

Body temperature is regulated by the blood vessels and the skin. Most cooling results from radiation of heat and evaporation of perspiration.

Our behavior is dependent upon operation of the nervous system and the glands. We inherit some types of behavior, but we learn most of the common acts which make everyday living possible.

Word list for study

ligament	adolescence	vein	saliva
tendon	medulla	plasma	intestine
carbohydrate	instinct	protoplasm	enzyme
calcium	emotion	kidney	capillary
alimentary canal	voluntary	cerebrum	red corpuscle
bile	stimulate	ganglia	membrane
artery	calorie (food)	intelligence	adrenal
lymph	phosphorus	involuntary	cerebellum
white corpuscle	pancreas	gland	reflex
perspiration	gastric juice	vitamin	thyroid

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. The cells require a variety of foods to build protoplasm needed for growth and repair.

B. Work and production of energy take place in the cells as the result of oxidation of food.

C. The amount of energy in foods is measured in calories.

D. Digestion makes food soluble and changes it to forms which can be used by the cells.

E. The body is controlled by the nervous system and by chemicals produced in the ductless glands.

F. The skin protects the cells of the body and is the heat regulating organ.

G. Body movement is the result of the action of muscles upon the bones.

H. Foods are chemicals which can be detected by chemical tests.

I. Circulation of blood provides food and oxygen to the cells and removes wastes.

List of related ideas

1. All activities of the body take place in the cells.
2. Sugars and starches belong to

the class of foods called carbohydrates.

3. The best food class for fuel is fats.
4. The glands which produce perspiration are located in the skin.
5. In times of emotional upset the blood contains more sugar than is normal.
6. The long bones of the body are levers.
7. We can taste salt, sweet, bitter, and sour substances.
8. Chewing and wetting food is a physical change necessary for digestion.
9. Oxygen is carried by the red corpuscles of the blood.
10. The warmth of the body depends upon the chemical activity of the cells.
11. Evaporation of water absorbs energy from surrounding objects.
12. Starch, when mixed with saliva, is changed to sugar.
13. Every kidney tubule is in direct contact with capillaries.
14. Heat is lost from the body by radiation.
15. Carbon dioxide is produced each time a muscle cell contracts.
16. Gastric juice is secreted in the stomach.
17. The cerebrum controls most voluntary action.
18. When food is burned, the mineral matter remains as a white ash.
19. Beefsteak is rich in the food class protein.
20. Protein foods are broken down in the stomach.
21. Iodine mixed with starch gives a deep-blue color.
22. Carbon dioxide is carried in solution in the blood.
23. Food combines with oxygen in the cells.
24. Number of calories in food is measured by burning the food in a can surrounded with water.
25. The most important part of the entire digestive system is the small intestine.
26. The voluntary muscles, marked by crosswise stripes, move the bones.
27. Food is used in nerve cells to produce electric currents.
28. A large calorie is 1000 small calories.
29. The body must have a balanced diet for health.
30. Sensations are carried by nerve cells.
31. Food substances necessary for growth and health, which are found abundantly in milk and green vegetables, are vitamins.
32. Kidneys take wastes directly from the blood.
33. Few bacteria pass into our bodies except through the mouth and nose.
34. Fats and proteins are made soluble in the small intestine.
35. Calcium and phosphorus are needed especially for bone growth.
36. Fehling solution or Benedict's solution turns brick red when heated with some kinds of sugar.
37. A potato, an apple, a piece of chocolate candy, or a tablespoon of butter each furnish about 100 calories.
38. Movement is the result of the contraction of muscle cells.
39. Vitamins are essential for normal health and growth.
40. Protein is turned yellow by nitric acid and is turned orange by adding ammonia.

Hawaiian Pineapple Company, Ltd.

Pineapples are fruits, but they grow in a manner not common to our other fruits. They provide the same essential food materials found in fruits grown in this country.

Some things to explain

1. Why must everyone eat protein? What are good sources of protein?
2. How may one know when his diet is balanced?
3. How can one determine which are the cheapest foods?
4. What part in the use of foods does each of the following systems serve: digestive, circulatory, respiratory?
5. Why is it possible that essential food materials may still be undiscovered?
6. Why are food advertisers' claims generally unsound sources of information about diet?

Some good books to read

Bogart, L. J., *Nutrition and Physical Fitness*

Crampton, C. W., *Boys Book of Strength*

Crisp, K., *Health for You, Revised*

Keliher, A. V., *Life and Growth*

Miller, J. J., *Your Teeth and How to Keep Them*

Novikoff, A. B., *From Head to Foot*

Pattee, A. F., *Vitamins and Minerals*

Rose, M. S., *Foundations of Nutrition*

Williams, J. F., *Healthful Living*

CHAPTER

6

Conserving Our Health

Of the many things of value which we wish to conserve for future use, the most precious is health. Keeping healthy is not a simple matter, for our health depends upon many things. It depends upon discoveries made by scientists regarding the causes of and methods for fighting diseases. It depends upon sanitation in our homes and in our cities. It depends upon keeping our bodies in good condition. It depends upon good food, sleep, and exercise. It depends upon freedom from worry, fear, and too much excitement.

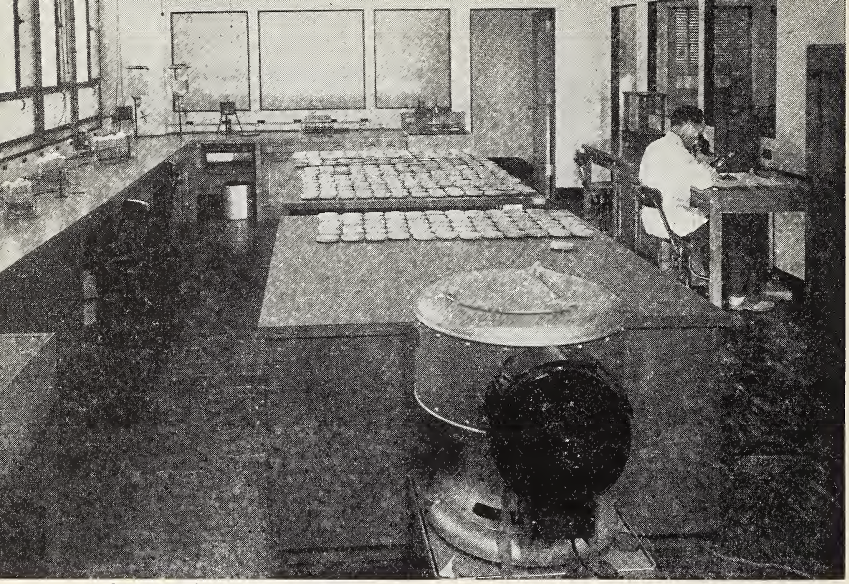
Despite the many factors which may produce sickness the average person is fairly healthy. The conditions under which we live make it easy enough for us to avoid many of the dangers which caused illness in the past. Our water and food supplies are usually safe. Our homes are the cleanest in the world. Our neighbors usually have habits of cleanliness and keep themselves healthy so that they do not carry disease germs to us.

And yet almost everyone should be even more healthy than he is. In any group of school children flat feet, colds, decayed teeth, diseased tonsils, malnutrition, and other defects are common. The average 14-year-old pupil is ill often enough to spend five days in bed at sometime during each year. Many thousands of high school boys and girls are in hospitals suffering from tuberculosis. Many people die from smallpox and other preventable diseases.

The battle to conserve our health is never won. As long as people exist, there will be bacteria that are adapted to live in their bodies and produce sickness and death. We have before us a problem that is a constant challenge.

Some activities to do

1. Collect advertising of faith healing, mystic sciences, and similar supposed helps to mental powers, and examine their claims. Try to show that these claims do not make sense, that their use of scientific vocabulary is mis-



Minnesota State Board of Health

In a modern laboratory, disease bacteria are studied under carefully controlled conditions. Petri dishes and culture tubes are in use. The machine in the foreground is a centrifugal separator.

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leading, and that they are designed to make money for the operators.

2. Visit your community health agencies, including the city water system and sewage disposal plant.

3. Make a study of materials in your home medicine chests. Have each pupil make a list of all drugs, antiseptics, laxatives, medicines, etc., in the home supply. Collect these lists without the names of the pupils on the reports. Study the lists in an attempt to find how the use of drugs in your community might be improved.

4. Make a study of causes of absence from your school for the past two or three months.

5. Make a list of unfounded health beliefs common in your community, and explain why they are unfounded. Find advertisements for fake health systems, and explain why they are unscientific.

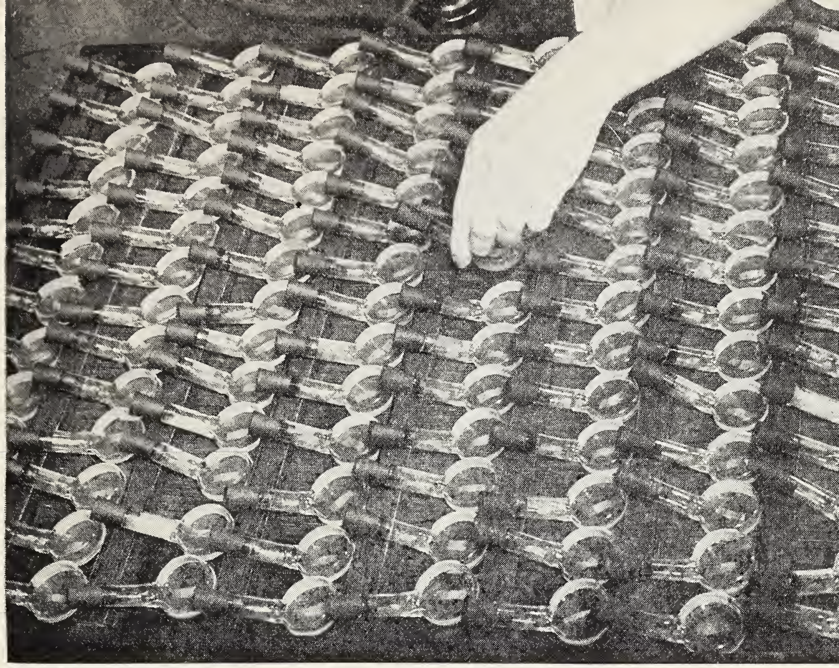
6. This activity is required of every pupil. Count off the class in pairs. Preferably let friends work together. Spread newspapers on the floor. Practice artificial respiration until the "victim" is forced to breathe because of the efforts of the pupil working. Practice to maintain good rhythm. Exchange places frequently.

7. Locate on yourself or another pupil every pressure point shown in the diagram on page 309.

Some subjects for reports

1. The false and misleading claims of many cosmetics advertisers

2. The manufacturing and raw materials of cosmetics



U. S. Public Health Service

In these flasks cancer cells are grown for study. By careful chemical feeding of the cells they can be grown without use of experimental animals.

3. A study of all accidents reported in your paper for one week

4. False and misleadng claims of health food advertisers

5. False and misleading advertising of alcohol and tobacco

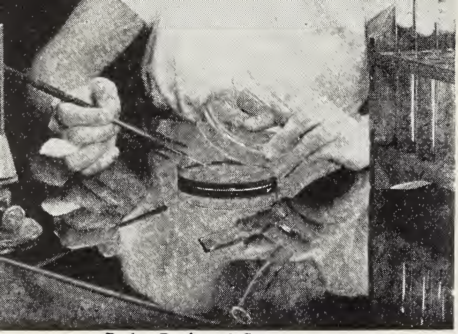
6. Co-operation in local X-ray tests

7. The work of your local antituberculosis association

8. The several discoverers of anesthetics and early difficulties with their use

1. How has knowledge of medicine developed?

We have come as a matter of course to depend upon medical knowledge to protect us from disease. Such protection has not long been available, nor is it yet available to people of all nations. For modern medicine is a recent science. It has developed from the study of methods of isolating bacteria, from the discovery of use of antiseptics and anesthetics [ăn′ĕs·thĕt′ĭk, a drug which causes loss of feeling] in surgery, from the use of chemistry in purifying and manufacturing drugs, and from other scientific discoveries. Scientific medicine is less than a century old.



Parke, Davis and Company

Bacteria of a single type are transferred from one culture to another by dipping them on the point of a needle. The needle is sterilized in the flame of the burner.

How did modern medicine begin? Ancient medicine developed slowly because of the lack of useful methods of research. The familiar tricks of medicine men, such as making brews of roots, muttering prayers, using charms, and other equally useless activities, slowly gave way to a small amount of medical knowledge developed by trial and error methods. Hippocrates [hĭ·pŏk′ rȧ·tēz], a Greek physician who lived about 2400 years ago, described methods of giving medical examinations, described many diseases, and gave directions for their treatment. The treatment was not often successful. Some 500 years after the work of Hippocrates another Greek, Galen [gā′lĕn], added some information to medical knowledge gained by dissecting animals and studying the arrangement of the organs in the bodies of these animals. From such study he tried to figure out the probable arrangement of the human organs. He also wrote a medical encyclopedia.

This work of Galen—including all the errors—was used as a basis for medical thinking for more than 1400 years. A few discoveries were made by Arabian physicians during this time. But it was not until the work of Vesalius [vė·sā′lĭ·o͝os] that the correctness of Galen's information was seriously questioned. Vesalius studied human bodies and became familiar with the human skeleton. To the knowledge of the ancients, there was gradually added the knowledge of surgery and of many simple medical treatments. It was learned from the work of Semmelweiss [zĕm′ ĕl·vīs] that if a surgeon washed his hands in chlorine water, he did not spread infection from one patient to another, but it was not known why. Most surgeons ignored such "unscientific" advice, and their patients generally died. It was in the 1620's that Harvey published proofs of his discovery that the blood circulates through the body.

How did study of bacteria develop? The discovery of the importance of bacteria in causing disease was a slow process. A microscope powerful enough to show bacteria was made by Van Leeuwenhoek [vän lā′vĕn·ho͝ok′] in 1683. Being able to observe bacteria through a microscope did not prove their relation to disease, of course, but it made the study of bacteria possible. You are familiar with the work of Louis Pasteur in proving that bacteria caused anthrax and

chicken cholera. Knowing the cause of these diseases, Pasteur developed the first vaccines that were worked out as the result of purely scientific approaches to the problem. Pasteur's inoculation of a boy to prevent rabies followed by about 90 years Jenner's discovery that the virus [vī′ rŭs, a disease-producing protein chemical] of cowpox could be used to prevent smallpox. Jenner, however, did not develop scientific proofs of the steps which made vaccination possible, nor did he know what caused the disease.

A great German scientist, Robert Koch [kôk], developed the first complete proof that a single type of bacteria caused a specific disease. He developed four laws describing steps in the proof: (1) The bacterium must be found in the body of the sick person or animal; (2) a pure culture of the bacterium must be made; (3) another animal inoculated with the bacterium must have the disease; and (4) the bacterium must be found in the body of the second animal.

According to Koch's method, a pure culture of bacteria is made by spreading infected material on a sterile [without germs] gelatin plate. On such a plate, each bacterium develops into a colony of bacteria. A single colony contains only one type of bacteria, although there may be other colonies made up of other kinds of bacteria present on the same gelatin plate. From one of these colonies the suspected bacteria are taken on the tip of a needle and placed on a second culture plate to grow. In this way, various suspected bacteria may be sorted out for study.

Parke, Davis and Company

Here the surgeon is performing an operation inside the abdomen of the patient, who is covered. The assistants and nurses help with the operation, hand the surgeon instruments, and give the anesthetic. What precautions against infection can you see?

Koch used this method to prove that tuberculosis is caused by a bacillus [a rod-shaped bacterium]. He took from the lungs of a patient who died from tuberculosis a tubercle [a round growth] and stained the material it contained for examination under a microscope. He found this bacillus was present in all tubercles examined and not present in the lungs of healthy persons. Then the bacillus was grown in a pure culture and injected into a healthy guinea pig. The guinea pig took tuberculosis and eventually died. Koch then examined the tubercles from the lungs of

the dead guinea pig and found the same slender bacillus with which he started.

This discovery of the germ of tuberculosis was the beginning of similar studies of many other diseases.

Can surgery save lives? There are some diseases which cannot be cured by ordinary treatments with drugs, nor can they be prevented by inoculation. Some such diseases may be cured quite successfully by surgery. The most common of the major surgical operations is for treatment of appendicitis. The safety with which this operation is possible today depends upon two important discoveries.

An English surgeon, Lister, read of Pasteur's discoveries of the relation of bacteria and disease. To prevent the entrance of disease germs into wounds created by surgery, Lister used carbolic acid for an antiseptic. He dipped sponges and instruments into the solution and kept towels soaked with the solution around the wound. He washed the wound with carbolic acid solution, and for a while even sprayed the air of the room with it.

Today the use of such powerful and irritating substances is unnecessary. Instruments are made sterile by boiling, boiled rubber gloves are worn, and sponges are baked to kill germs. In many modern operating rooms the air is sterilized by ultraviolet light. The surgeon wears a mask to prevent spray from his mouth entering the wound. The skin to be operated upon is washed with pure alcohol.

A second important factor in making surgery safe is the use of anesthetics. The discovery of anesthetics is shared by a number of men who carried on the work at the same time. In 1842 ether was first used to produce unconsciousness in patients to prepare them for a surgical operation. Other chemicals, nitrous oxide and chloroform, were also used. Any one of these three gases can be breathed into the lungs and absorbed, and soon causes a deep sleep. Not only does use of an anesthetic reduce the pain from operations, but it actually protects the nervous system from shock resulting from pain. Before the discovery of anesthetics, nervous shock following operations was a frequent cause of death.

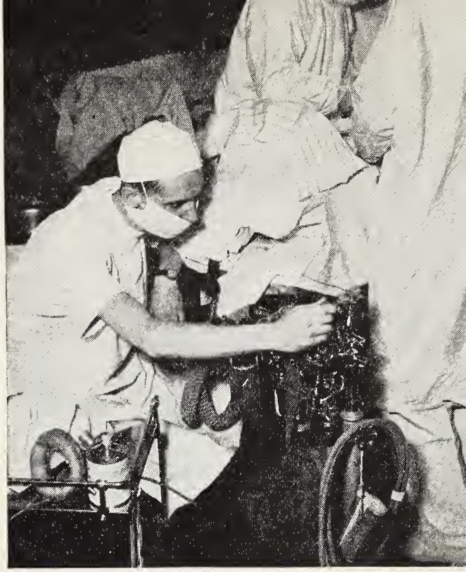
While no operation can be said to be entirely safe, if an operation is undertaken while the patient still has a reasonable chance to live and is performed by a competent surgeon, the chances of recovery and improved health are excellent. Many lives are saved daily by operations for tumors, appendicitis, cancer, and other less-known illnesses.

Why is public health improving? The improvement in the general health of people does not depend entirely upon medical care. Much of it results from improved nutrition, better sanitation, cleaner and warmer houses,

and improved safety. These factors have greatly reduced the death rate of babies and children.

Babies have better chances to live today than ever before. The baby born in a hospital, kept in a glass-walled room, fed pasteurized or mother's milk, and kept away from adults is very likely to live. Contrasted with the treatment of babies born 100 years ago, modern babies encounter little risk. The old practice was for the baby to be born at home, to be handled by any adult who was around, to be fed impure milk or even solid foods, and to be given water containing bacteria.

The practical test of the value of modern medicine is in the reduced death rate, in the reduced amount of sickness, and in the increased average age of the population.



Parke, Davis and Company

When "gas" is given as an anesthetic, not much is visible. The patient is covered with a cloth, while the attendant regulates the flow of the anesthetic through the valves and tubes.

Exercise

Complete these sentences:

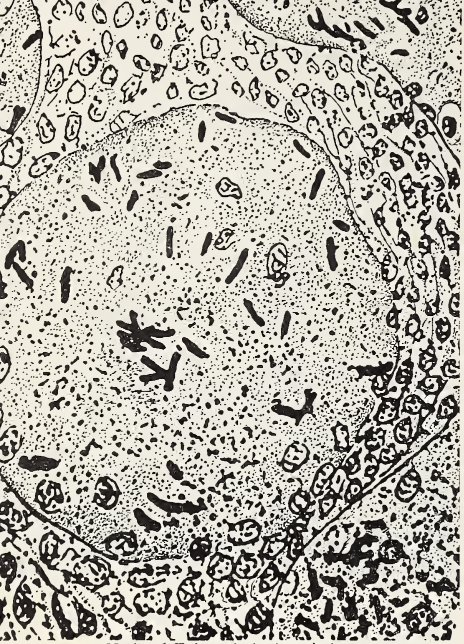
A chemical which retards growth of bacteria is an —1—. A chemical which causes loss of feeling is an —2—. Semmelweiss used —3— water as an —4—. —5— proved that blood circulates. Putting a chemical into the body to prevent disease is called —6—. The bacterium proved by —7— to cause tuberculosis is a —8— type. Lister used —9— for an antiseptic. Ether is a commonly used —10—.

2. *What diseases are most dangerous?*

Because of man's conquest of disease, many of the fatal diseases of the past are no longer a source of danger to the average person. Although the plague, leprosy, typhus, smallpox, typhoid, and many other diseases are as deadly as ever, we know how to prevent their spread, and we need not fear them if we continue to keep them under control.

There are two types of dangerous illnesses today. The first type is that which is fatal. The second is the type which causes serious aftereffects or which causes much suffering and loss of time.

What are the leading causes of



National Tuberculosis Association

The electron microscope photograph from which this drawing was made magnified tuberculosis germs 42,000 times. The rod-shaped black objects are tuberculosis bacilli.

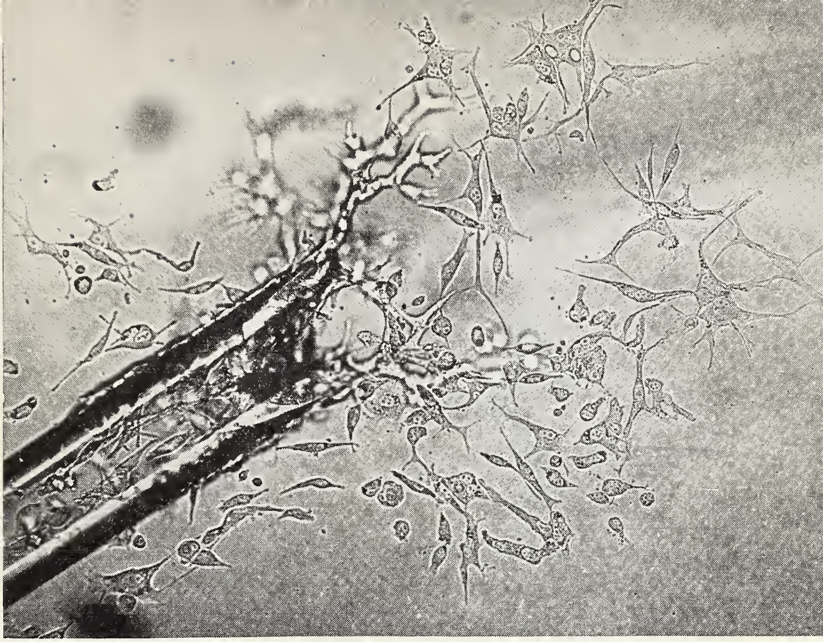
death? At present more people die of heart disease than from any other cause. There are many causes of heart disease. Among them are infections resulting from many other diseases which are not directly fatal. One such disease is rheumatic fever, which particularly affects children. Another disease, syphilis, is generally transmitted through the reproductive organs. Some heart disease may be caused by alcohol, some by misdirected nervous energy. Most deaths from heart disease come to those who are in later middle age or in old age, although the beginning of the illness may have been the result of an earlier infection. Even for children heart disease ranks third as a cause of death.

Cancer is second of the most deadly diseases. It occurs when certain cells of the body grow at an unusual rate and in unusual ways. These wildly-growing cells may destroy normal tissue or may manufacture substances disturbing to the organs of the body. While cancer may be controlled if discovered in time, its cause is not yet known, in spite of the efforts of thousands of scientists and the expenditure of great sums of money. Cancer is a leading cause of death at all ages.

Violence—automobile accidents, burns, falls, murder, suicide, industrial accidents, sports accidents—is a serious cause of death. It is the leading cause of death among school children and is too often the result of their lack of education regarding rules of safety.

The third and fifth causes of death result from the breaking down of the blood vessels of the brain and infection and breaking down of the tissues of kidneys. These diseases also are most likely to attack the older people.

Pneumonia and influenza are still deadly diseases. There are more than 30 types of pneumonia. Treatments for many types have been worked out through use of serums and drugs. Pneumonia is contagious and may attack people of any age. It most often follows a cold, influenza, or



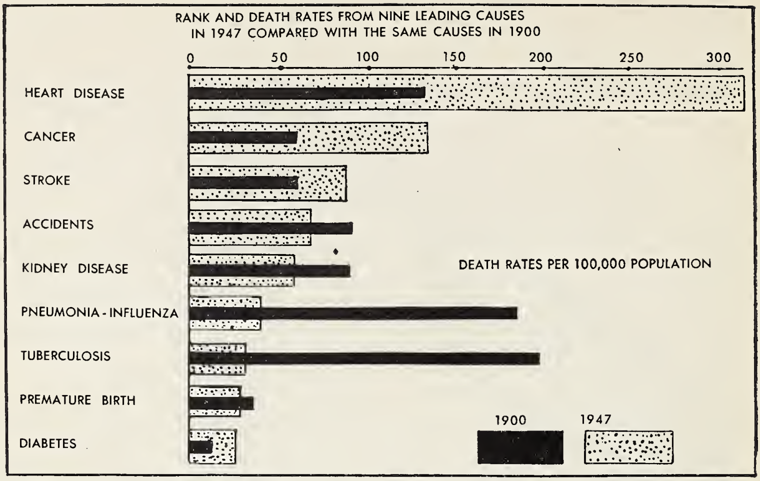
U. S. Public Health Service

These irregular-shaped objects are cancer cells, greatly magnified, which were grown in a culture.

some other weakening disease. To avoid pneumonia one cannot be too careful to remain in bed until he is completely recovered from colds and influenza.

Tuberculosis is one of the few diseases that is more common among people in their teens and twenties than among older persons. It ranks first in causing death in this age group, and it attacks those who are in poor physical condition. Tuberculosis is contagious and is spread by kissing, by mouth spray, by putting infected articles into the mouth, and in other ways. Girls are more likely to have tuberculosis than are boys.

Many deaths occur in infancy. Many babies are born without enough vitality to live or lack full development of all their organs. In some cases a lack of food or the illness of the mother may be a cause of the death of the baby. Ninth in the list of deadly diseases is diabetes, which is caused by destruction of small bodies in the pancreas. These bodies normally manufacture a chemical which regulates the use of sugar in the body. If they are destroyed, sugar accumulates in the blood and is eliminated through the kidneys, while the patient slowly starves or dies from infection resulting from the



The nine most deadly diseases of 1947 are shown in order in this chart. Which diseases are now more deadly than they were in 1900? Which less? Some of the more deadly diseases of 1900 are not shown on this chart because they have since been brought fairly well under control.

upset condition. Diabetes can be controlled by use of insulin which is injected into the blood stream. Many people who have diabetes live long and useful lives because of the discovery of insulin and because they eat carefully selected foods.

You will note that most of the deadly diseases are those which attack older people. Relatively few young people die today of diseases of youth. Young people today generally die of the same diseases as do older people. This situation results, of course, from reducing the number of deaths of younger people from infectious diseases.

Never before have many people lived long enough to die of many of these old-age diseases. The average age at death today is more than 67 years, yet only 110 years ago it was about 30 years. It is said that the average age at death in ancient Rome was 19 years.

What are the disabling diseases? The common cold causes more days lost from normal activity than does any other disease. Colds are contagious. They are caused by a virus. Colds cause few deaths, but they prepare the body for serious aftereffects. There is no effective cure for the common cold although if certain drugs are used very promptly at the beginning of a cold, it may be prevented from developing. The old-fashioned remedies—drinking alkaline solutions or fruit juices, use of aspirin, taking cold pills, use of vaccines, eating onions, use of ultraviolet lamps,

changing climates, and wearing poultices—are of no use. Use of nose sprays is not only valueless, but often dangerous, for the spray may contain oil which enters the lungs, making a center of irritation in which pneumonia germs may lodge. Cough drops and sirups are merely flavored sugar and are useless. The only effective treatment for a cold which has really developed is to go to bed and to eat a reduced amount of food until recovery takes place. If a fever occurs, call a doctor. Doctors can prevent pneumonia and other serious aftereffects of colds.

The "cold" accompanied by a fever may be something more serious. Above all, do not have visitors or go into crowds to spread the cold to others.

Measles and scarlet fever produce serious aftereffects. Both may cause permanent injury to the eyes or injury to the ears resulting in loss of hearing. Pneumonia may follow either disease. It is essential that good medical care be given for measles and scarlet fever and that quarantine be observed. Measles is extremely contagious, and a serum made from human blood is the only means of protecting the body against this infection that has been found. Scarlet fever, of course, may usually be prevented by inoculation.

Infantile paralysis is not a common disease, but it frequently causes serious injury to the muscles of the body. Recovery may be followed by loss of use of the limbs. Treatment consists of tedious massage, exercise, and effort in learning to use the injured part of the body. Many do recover entirely, but the effects are so serious that taking precautions against infection is essential.

The exact permanent effect of contagious disease on the body is not well known. Injuries, infections, and even minor sprains may apparently be cured and forgotten, only to reappear as causes of other more serious types of illness in old age. Just how many deaths result from heart disease caused by injury suffered in youth is impossible to know. There seems to be no logical reason why people should ever die of old age, for age itself is not a cause of death. Yet no person has ever lived on indefinitely, for so many strains occur in ordinary living that eventually we all die.

Exercise

Complete these sentences:

The deadly disease most dangerous to teen-age people is —1—. The disease most likely to follow careless treatment of a cold is —2—. School children are in greatest danger of death from —3—. —4— is a disease resulting in loss of sugar from the body and is treated by use of —5—. The best treatment of a cold is to —6—. Loss of hearing may follow —7— or —8—. Scarlet fever may be prevented by —9—. A —10— made from human blood protects against measles. The most deadly disease is —11—, and next in causing death is —12—.

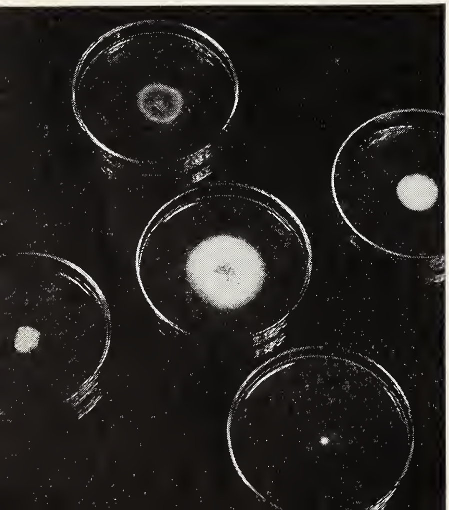
3. *Is it necessary to be sick?*

In order to keep ourselves well, we can approach our problem from two directions. One includes all the positive acts of healthful living, such as eating a balanced diet, obtaining proper rest, exercising moderately, and keeping clean. The other approach is to defend ourselves from disease as well as we can. Ordinary methods of healthful living will not protect us from all diseases and will not cure us of many diseases.

What are the causes of disease? Most diseases fall into one of three groups. The failure of some organ of the body to develop normally or to function normally results in sickness. Diabetes is a disease of this type, for the pancreas does not produce the insulin needed to control the use of sugar in the body. A second type of disease results from lack of some material needed by the body for its proper functioning. These diseases include those caused by lack of necessary proteins, vitamins, or minerals in our diets.

It is not enough to know that germs cause disease. It is essential to know what germs cause what disease. Here are five types of fungi which cause five different types of skin disease.

Parke, Davis and Company



A third type of disease results from infection by germs. These diseases include all those listed in the table and many more. The word germ is used in a general way to include any organism which may make us sick, but it particularly applies to those that are microscopic or smaller. They include the bacteria, the viruses, and the protozoa.

Bacteria are of three general types: the round, or coccus type; the rod-shaped or bacillus type; and the spirochete [spī′rō·kēt] or spiral or long and twisted type. They are all simple plants which cannot make their own food. They produce illness by actually destroying tissues and by producing poisons which circulate in the blood stream. These poisons are called toxins.

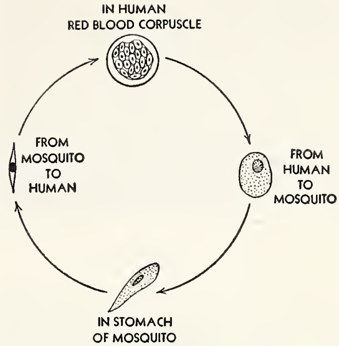
The viruses are so small that they cannot be seen by use of an ordinary microscope, although they have been photographed by electron microscopes. The average bacterium is about a hundred times as large as the largest virus. Viruses cannot be grown on cultures of gelatin or other nonliving food as bacteria can,

but must be tested on living materials such as mice or hatching eggs. A virus can grow and divide, but it still may be a complex protein molecule instead of a living organism. Viruses cause many diseases in somewhat the same way that bacteria do.

Protozoa are one-celled animals, generally somewhat larger than the bacteria. Two common diseases caused by protozoa are malaria and amoebic dysentery [ȧ·mē′bĭk dĭs′ĕn·tĕr′ĭ].

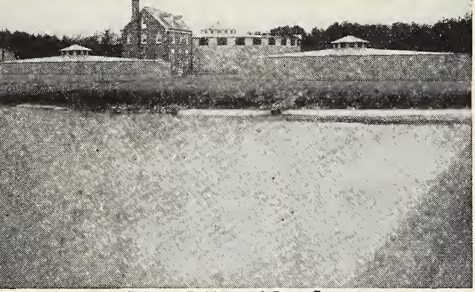
Other diseases may be caused by worms, either large worms which live in the intestine or very small ones which may live in various organs such as the muscles and liver.

How is disease prevented? We have four general methods of preventing disease. The first is to cure sick people and to keep healthy people from coming into contact with them when they can spread disease. The second is to build up immunity in the body by vaccination or inoculation, so that the natural defenses of the body are strengthened. The third is to get rid of animal carriers of disease, so that they cannot spread the disease to people. Some animals have diseases which people may contract, and other animals are carriers of germs from person to person. Rats have bubonic plague. Flies carry tuberculosis germs. The fourth method is to provide sanitary conditions so that we have only pure food, clean water, and healthful living conditions in general.



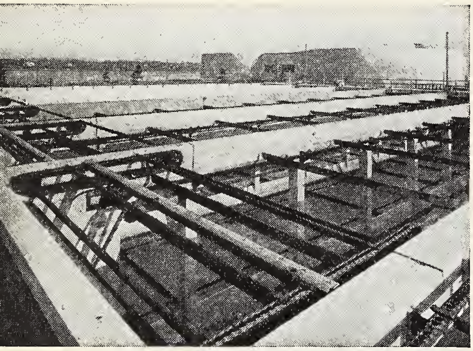
The protozoa which causes malaria goes through several forms as it is passed from mosquito to human and back to mosquito.

The body itself has several natural defenses against disease, but we can do little to improve these defenses except to maintain good body condition and to avoid cold, fatigue, worry, and malnutrition. These four troublemakers lower resistance to many diseases. The natural defenses include the skin, which keeps out some germs and contains chemicals unfavorable to the growth of others. The white corpuscles of the blood actually capture and digest germs, and so do certain cells in the lymph glands and in the liver. When germs invade the body it produces chemicals called antibodies which make the body a poor environment for the germs. No matter what disease is considered, there are many people whose natural defenses can overcome it, and these people will recover. Unfortunately, there are many people whose defenses are not strong enough to avoid being ill, or even dying. These



Chicago Bridge and Iron Company

This is a water-treating plant.



Department of Public Works, New York City

These are settling tanks of a sewage-disposal plant.

sick people also generally spread germs to others.

Can the community protect us against disease? The least that any community, however small, can do to protect its citizens is to provide pure water and to regulate the sale of milk. Inspecting stores and restaurants, providing opportunities for recreation, controlling the ill, arranging for hospital treatment for the poor, and eliminating menaces to the health of its citizens are among the many added responsibilities of larger communities.

To provide pure water, it may be necessary only to find a pure supply and to deliver it through pipes in a sanitary manner. However, most communities must purify their water by killing disease bacteria in it. This is accomplished by adding chlorine to the water and storing it for 24 hours in order to give the chlorine time to act. If the water is muddy, the most economical way of clearing it is to run it through a settling tank. To speed the settling, a floc is made by add-

DISEASES	CAUSES	CARRIER, SPREAD	PREVENTION, CONTROL
Tuberculosis	bacillus	contact	avoid contact, good health
Diphtheria	bacillus	contact	antitoxin and toxoid serums
Bubonic plague	bacillus	rat fleas contact	kill rats, vaccine, drugs
Whooping cough	bacillus	contact	serum
Typhoid fever	bacillus	water food, contact	pure food, water, vaccine
Meningitis	coccus	contact	drugs, serum
Pneumonia	coccus	contact	drugs, serum
Scarlet fever	coccus	contact	vaccine
Syphilis	spirochete	contact	drugs, avoid contact
Influenza	virus	contact	vaccine
Smallpox	virus	contact	vaccine
Measles	virus	contact	serum
Yellow fever	virus	mosquito	vaccine
Chicken pox	virus	contact	none
Malaria	protozoa	mosquito	drugs
Amoebic dysentery	protozoa	water	drugs

ing lime and alum to the water. These chemicals combine to form a fibrous, jelly-like compound which settles and takes with it fine suspended particles. If the water is run through a filter, the floc increases the effectiveness of filtration.

It is almost impossible to produce milk pure enough to be safe for use without pasteurization, and it is probably not good economy to try to do so. It is a simple matter to heat milk to 145 degrees Fahrenheit and then to cool it to 50 degrees. Not only is such milk safe, but it keeps better, which is an important factor in selling milk at a profit.

The community has the responsibility of seeing that sewage does not contaminate the water supply. Another important responsibility is to provide medical care for the poor, for it is often in the poor sections of cities that epidemics start. All citizens are in danger when any are ill.

DEMONSTRATION: HOW IS WATER PURIFIED?

What to use: Test tubes, one-hole stopper and delivery tube, manganese dioxide, hydrochloric acid, alum, calcium oxide or limewater, soil, filter paper, funnel, rack, pond water.

What to do: Mix soil and water to make a muddy suspension. Set one test tube of the suspension aside to let it settle. Filter another test tube of water through the filter paper.

Dissolve a lump of alum in one-eighth of a test tube of hot water, and add it to three-fourths of a test tube of the suspension. Add one-eighth of a test tube of limewater to the mixture, and shake it. Set it beside the other tubes.

Prepare chlorine by pouring 5 ml. of hydrochloric acid over a gram of manganese dioxide. Warm it gently. Bubble the gas into tap water. Smell and taste the tap water. If pond water or water from the aquarium is available, examine it for small organisms. Then bubble chlorine into the water, and after a few minutes examine it again.

What was observed: Compare the appearance, probable cleanliness, and freedom from bacteria of each of the samples.

What was learned: How is water purified?

Exercise

Complete these sentences:

The two most common causes of contagious disease are —1—, which are small living organisms, and —2—, which are too small to see through a microscope. We are —3— to a disease which we cannot catch. Germs produce illness by destroying —4— and by producing —5— which poison the body. One-celled animals which cause disease are called —6—. The —7— miscroscope magnifies objects thousands of times. Sediment may be removed from water by —8—. Bacteria in water are killed by —9—. Alum and lime combine to form a —10—.

4. How are diseases controlled?

If it is known that there is danger of a disease, every one of us should have ourselves made immune to it if any method exists for doing it. If we should become ill, we have the responsibility of obtaining the best possible medical care. Fortunately, there have been in recent years many important gains in methods of preventing and curing disease. These generally depend upon use of chemicals prepared by various methods.

A drug is a chemical which produces some desired change in the condition of the body. Drugs used to cure disease generally slow the growth of germs so that the natural defenses of the body have a better chance to work. Vaccines are weakened or dead germs which are injected into the body to stimulate the production of antibodies. Serums contain antibodies from some source outside the body of the person treated. Serums may be obtained from the blood of horses or of chicks or of people. Serums can be obtained only from an organism which has overcome the disease germs.

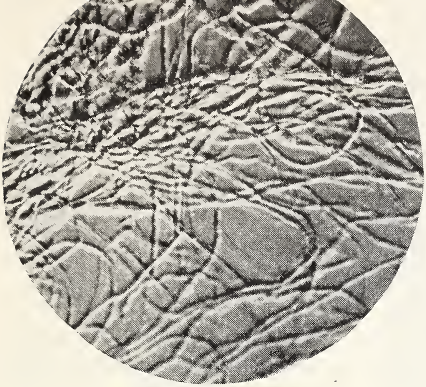
Antitoxins are contained in the blood of people or other animals which have had a disease and have overcome the toxins produced by disease germs in the body of the sick person or animal. Toxoids are made by weakening antitoxins and are put into the human body so that it may develop its own antitoxins.

How is immunity developed? Immunity to some diseases may be developed only by coming into contact with the germs, and by building within the body the necessary antibodies to resist further growth of the germs. We never become permanently immune to some diseases, such as the common cold, pneumonia, and influenza. Some people may become immune to a disease without actually becoming ill.

Immunity to many diseases can be acquired by use of vaccines, serums, toxoids, or antitoxins. Immunity to some diseases should be provided to babies soon after birth. Diphtheria, whooping cough, scarlet fever, and measles are particularly injurious to young children. Everyone should be vaccinated against smallpox

This little fellow is in danger from an epidemic of measles threatening a children's hospital. He is being given protection by inoculation with a serum developed from blood of immune persons.

Science Service



Merck and Company, Inc.

The organism at the left produces penicillin. The one at the right produces streptomycin. These are microscope pictures.

in childhood, and again as often as necessary.

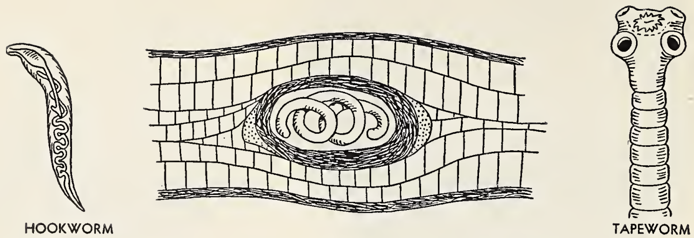
Immunity to other diseases may be acquired if there seems to be a need for it. Immunity from influenza may last only a few months, and it is important to be vaccinated against this disease at the time an epidemic seems to be developing. Some diseases are not threats to the health of people under good sanitary conditions. There is ordinarily no need to be vaccinated against yellow fever or cholera. Vaccination for rabies is used only after a person is bitten by an infected dog.

If a large proportion of the population of any region is immune to a disease, there are fewer to carry and spread it, and thus those who are not immune are in less danger of coming into contact with a person sick from that disease.

What is a specific drug? A specific drug is one which cures a certain disease. A drug may be specific for one or more diseases, and entirely useless or harmful when used for treatment of other diseases. Before 1930 there were few specific drugs available, although many drugs were used. Most of the earlier drugs listed in older books had little value for curing any disease.

The first specific drug which had wide use in treating illness was a chemical dye. It belongs to a large group of chemicals called sulfonamides. The drugs of this group have *sulfa* in their names. After the first drug of this group was developed, several others were found. Each of the sulfa drugs has its specific uses. Properly used they will cure a great number of diseases. Unfortunately they are not entirely safe to take unless very carefully used.

Another group of drugs is made from chemicals given off by molds and related fungous organisms. The most familiar of these are penicillin and streptomycin. The mold gives off drops



Specific drugs exist which can be used to rid the body of hookworms and tapeworms, but none exists to free the body of the trichina worm which buries itself in muscle tissue (*center*).

of a liquid containing the drug. These drugs are also specific for a number of dangerous diseases.

There is no single drug which will cure all diseases. There is no drug which will cure some diseases. There is no effective drug which is safe to use without careful medical direction and supervision.

What are patent medicines? So-called "patent medicines" are neither patented nor medicines. The name or label of the bottle is copyrighted in the United States Copyright Office. The makers are required to avoid using certain drugs, such as opium, strychnine, and other very dangerous substances. The Federal Food, Drug, and Cosmetic Act prohibits making specific promises to cure a disease on the label of the container.

That the American people are in need of correct information on health problems is evidenced by the wide use of patent medicines. Advertisements of patent medicines reach the eye on every hand—on billboards, in magazines, and in newspapers. One sees the shelves of drugstores loaded with packages containing patent medicines. The false claims of these medicines enter our homes over the radio.

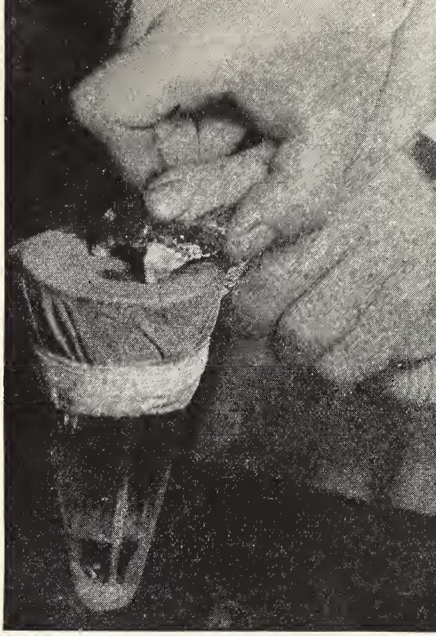
About half the money spent for medical care in the United States is wasted on patent medicines. There are several factors which explain this situation. One factor is the ignorance of people concerning some of the most elementary facts regarding health. Another factor is the publicity that patent medicines receive as a result of wide advertising. And a third factor is that when people are sick, they become desperate and are willing to try anything in the hope of getting well.

Most patent medicines fall into one of three classes. Some are advertised for their effect as tonics. They often contain a large amount of alcohol. The sedatives depress the nerves and thus have a soothing effect. Then there is the group of patent medicines that contain those drugs advertised as cures for all sorts of diseases, ranging from cancer to tuberculosis.

Some patent medicines contain such common things as sugar and baking powder, which, of course, are harmless but which are also worthless because they can have no effect in curing sickness. But many patent medicines contain substances which are positively harmful to the body. One radium "cure" actually contained radium and filled the bones of a man it killed full of radium. His bones contained enough radium to make light streaks when placed on a photographic film. Many patent medicines contain large per cents of alcohol. Through the regular use of patent medicines, it is possible to acquire an appetite for alcoholic liquors and possibly the drinking habit.

One of the harmful results of depending on patent medicines to cure illness is that the average person does not know whether or not he is getting the proper treatment for his illness. Yet many people insist on treating themselves anyway. A person who cannot tell what is wrong with his health cannot effect a cure. Patent medicines are of no use even when one knows what disease he has.

Perhaps the greatest danger involved in the use of patent medicines is not in the effect they produce on the body but rather in the feeling of false confidence which their use brings. Meanwhile the disease may be growing worse. While a sick person is wasting time on the useless drinking of flavored water, one of the deadly diseases may be gaining headway. Self-treatment of tuberculosis or cancer will be fatal.



Sharp and Dohme

To make a serum for protecting against rattlesnake bites, poison is extracted from the fangs of the snake. The fangs are pressed through a sheet of rubber.

The fact that some people who treat themselves get well proves that a good share of illnesses are not fatal, no matter what one does. Treatment by an unskilled person is of no value whatsoever.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: specific drug, vaccine, serum, antitoxin, patent medicine, alcohol, sleep, advertising, serum, sulfa, molds.

5. Why do people use drugs?

Mental ill health may take many forms, such as nervous breakdowns, tendencies to show off, extreme sensitiveness, fear of failure, lack of self-confidence, nervous movements, violent temper, or fear of strange places. One of the most serious effects of mental ill health results when the ill person turns to drugs to obtain sleep, to gain a feeling of vitality, or to escape from his troubles. Others less ill mentally turn to patent medicines to treat their difficulties, obtaining no real relief except through a feeling that they are doing something.

How is mental health affected by alcohol? Normal people do not drink alcohol to excess, and most of them do not drink it at all. People who drink excessively do so to escape from some fear, uncertainty, or unpleasant situation. If you are influenced by others to drink, you may start a habit which will cause you, too, to develop some form of mental sickness. For the effects of alcohol on the body are such that it not only gives the mentally ill a means of escape, but it also causes changes in the body and in the emotional processes which produce mental ill health.

The immediate effect of alcohol is quite apparent. A small amount decreases a person's ability to be self-critical and weakens judgment. That is, a person who is typing while mildly intoxicated may think he is doing better than usual, while actually he is typing more slowly and making more errors. In the first stages of intoxication, reckless acts seem reasonable, money seems to lose its value, and people seem different.

The second stage of intoxication involves loss of muscular control and lack of mental clearness. The gait becomes uncertain, small movements such as eating or writing become difficult, speech is confused, and judgment is so poor that acts may be committed that are completely unreasonable. In this stage, an automobile driver cannot drive well enough to remain on the road. Possibly one-fourth of all fatal automobile accidents are caused in part by the drinking driver. Immoral acts of various kinds may result from lack of normal judgment of their consequences.

The third stage of intoxication is loss of consciousness. This loss may be temporary if not too much alcohol is taken. If a sufficient quantity has been taken, death will result, just as it will from a sufficient dose of any poison.

The immediate effect of alcohol on the body is chiefly through its action on the nerves. It is related chemically to ether, which dissolves the fatty substances in certain nerves and makes them unable to do their work.

Alcohol also withdraws water from the tissues of the body, and

to some extent upsets their normal functioning. The amount of upset is dependent upon the amount of alcohol taken.

While alcohol is not always the cause of mental disease, when a mentally ill person turns to alcohol to escape his problems, he becomes less able to solve his problems, and in addition alcohol upsets his physical health. There is a definite relationship between alcoholism and mental diseases of various kinds. Many drinkers never become seriously ill but are merely incompetent to get along in the world. They are unable to remain on a job long enough to get established, cannot keep out of debt, and do not enjoy normal types of activity. Alcohol may cause physical illnesses and injury to the stomach, liver, kidneys, heart, and arteries. Alcoholism, which results from excessive use of alcohol, is a disease which requires medical treatment.

Alcohol can easily become habit-forming. Not all who drink it will form the habit, but it is impossible to know in advance who such people are.

Traveler's Insurance Company

The hands of a person who uses alcoholic drinks are not safe on a steering wheel. Alcohol increases the time needed to react, decreases judgment, and reduces skill—three important factors in driving an automobile.

What are narcotics? Alcohol is generally classified as a narcotic. There are other narcotics which are less common, and still more deadly, than alcohol. A narcotic drug reduces the activity of parts of the brain. The particular effect of a narcotic depends upon the kind used. The commoner narcotics are opium, cocaine, and marijuana. They are sold in direct violation of state and federal laws. Anyone who has contact with them is dealing with criminals and running the risks attached to criminal acts.

Libbey-Owens-Ford Glass Company

Airline companies have rules severely regulating drinking by the pilots. When safety of plane and passengers depends upon clear thinking, alcohol is dangerous.

The drugs themselves produce marked permanent changes in the nervous system after a period of use. While it is perhaps possible to get rid of the habit of using these drugs, it involves a cure that is long, painful, and tedious. Death usually results within a few years from use of narcotics.

Marijuana is the drug that is most commonly sold by criminals to school children. Under the influence of this drug moral responsibility is lost, and crimes ordinarily regarded with horror may seem to be normal behavior. Marijuana is commonly made into cigarettes and may be disguised as one of the standard brands. Criminals make a practice of trying to form the drug habit among children in order to have buyers for the drugs later. Never, under any circumstances, take a cigarette from a stranger or an acquaintance whose reputation you have reason to suspect.

Do sleep-producing drugs affect health? The use of sleep-producing drugs other than narcotics is largely an adult problem, yet you should know about it. When people become nervously exhausted or extremely worried, they cannot sleep easily, as can a normal, healthy boy or girl who lives and exercises regularly. There are a number of sleep producers on the market. They do produce rest temporarily, but they also cause a loss of normal habits of going to sleep. These drugs all act upon the nervous system and produce a number of rather serious ill effects.

What are stimulant drugs? There was recently a fad among college students and some high school students of taking "pep pills" before examinations, the idea being that the brain is clearer when the drug is used. This is another popular notion that does not hold true when tested experimentally. Some experiments show that definite interference with learning results from use of this drug.

Possibly the least harmful of all stimulants is caffein in a pure form. It is found in coffee, which depends for its flavors upon oils that soon become rancid and difficult to digest. Caffein is used by truck drivers who must work all night and by others who must resist sleep. Sleep, however, is not something to resist but something essential to health. Use of a stimulant to keep one awake is always bad. The body uses up its energy faster than it is replaced, and dangerous fatigue results. Tea contains a drug similar in its effect to that in coffee. A third drug of this class is found in cocoa. Have you heard advertising over your radio recommending cocoa foods to help you sleep? Their actual effect is to keep you awake. Children should not use any stimulating drug, for they need sleep even more than do adults. In one bottle of some soft drinks there is about one half the amount of caffeine to be found in a cup of coffee. These stimulating drugs normally are not habit-forming.

Does tobacco affect health? If you formed your opinion from tobacco advertising, you might believe that smoking is actually normal, safe, and healthful. It is often evidence of lack of poise and maturity. It is a form of nervous habit with many people. Some psychologists say that many people smoke because they have never outgrown the infantile desire to have something in their mouths upon which to suck.

Tobacco, in spite of the advertising and fake science to the contrary, does have an undesirable effect upon the heart. It is irritating to the eyes, nose, throat, and lungs. Vision is less clear after smoking. Smoking affects the blood pressure, and the flow of blood to the skin increases. Its use does seem definitely to be related to shorter than average life. Smokers do not recover from some illnesses and operations as well as nonsmokers do.

Students who smoke are known to make poorer grades than those who do not smoke. Whether poor students smoke to try to make up in some way for their lack of ability or whether smoking interferes with thinking is not definitely known. It may be that good students are wise enough not to smoke, and poor students are easily taken in by advertising or the influence of friends who smoke.

Why do the mentally ill use patent medicines? Most of those who use patent medicines over long periods of time are suffering from mental ill health. Those who are suffering from physical illness and are using patent medicines do not continue for long periods of time. They may recover regardless of their use of the medicine, or become so much worse that medical care is required. Sometimes lack of medical care, due to use of patent medicines, results in the death of the patient.

Some people use poor health as an excuse either to escape their responsibilities or to provide a means of centering attention upon themselves by seeming to be ill. To these people patent medicines are a welcome help. They take the flavored water, bitter drugs, and salts with the air of one scarcely able to bear up under the cruelties of life. The medicine is a valuable stage property to help them in the act of seeming ill. These people probably harm themselves only slightly, even though they do not help themselves at all in overcoming mental ill health.

Exercise

Complete these sentences:

Alcohol attacks a fatty substance of the —1—. It is classed as a —2— drug. Other drugs of this class are —3—, —4—, and —5—. All these appeal most to the —6— ill and increase mental ill health by injuring the —7— system. A —8— causes sleep, and after continued use, death. A —9— speeds up use of energy or delays sleep. Patent medicines are widely used by the —10— ill.

6. Do good attitudes improve health?

The really healthy person is happy and has a general feeling of well-being. Part of this pleasant condition comes from a sound body; the other part from good mental and emotional attitudes. Unfortunately many people are constantly worried or afraid or overcome with a feeling of inadequacy or defeat. It is estimated that about one person in 10 will need definite medical help for his health because of emotional problems. Yet much can be done to prevent mental and emotional ill health, if people recognize the problem.

What is mental illness? There are two kinds of mental illness. One kind, the organic, results from injury to the nervous system by disease, drugs, violence,

American Red Cross

Any boy who runs all the risks shown here needs information about first aid. He is using the knife wrong, a hatchet is always dangerous, and what about the nails?

or improper development. This type of mental illness may result in paralysis, inability to remember, or completely abnormal behavior. Such organic mental disease requires expert medical help. It usually can be detected by specific physical symptoms or by studying brain-wave patterns. The brain gives off electrical waves which can be measured by a very sensitive galvanometer so that a record is made as a wavy line on a chart.

The other type of mental illness is called functional. Functional mental illness may vary just as much in severity as does physical illness. In extreme form it may appear as what was formerly called insanity, but is now called a psychosis. Very few people have psychoses, and those who do must have medical care in a modern hospital if they are to recover. In milder forms mental illness appears as a neurosis.

The problem of most people is to find solutions to problems which may lead to emotional difficulties. Much neurotic behavior results from failure to solve

Ewing Galloway

It is important to have fun! Boys and girls who know how to enjoy themselves in the company of others are building a good foundation for continued mental health.

problems of everyday living in a manner which is satisfactory to the individual. Such problems as getting satisfactory grades in school, getting into desired social activities, and getting along in the family are common causes of teen-age worries.

A healthy way to solve problems of this kind is to have more than one solution available. If you cannot make the best grades in school, you still can do the best work possible for you, and find your satisfaction in being friendly and helpful, or you can find some special skill which you can develop. If you cannot make the school dramatic club you can perhaps join some other group where you will have just as much fun. Do not consider failure to be a sign of personal weakness, if you have done your best. Failure is a normal experience, and normal people merely turn their attention to something else when they fail at one thing.

A second cause of emotional disturbance is a feeling of insecurity. This usually develops in babyhood, and is not easy to recognize in older people. If you are constantly worried that your parents like some other member of your family better than they do you, or that people will not like you, or that everyone "has it in for you" you may be suffering from feelings of insecurity. Such feelings are usually not justified, for people accept others for what they are. If you can develop a likeable personality and just average social skills in getting along with people, there is no need to worry about being accepted. Everybody feels lonely and insecure at times, and their failure to be friendly may lie in their own worries instead of in your lack of appeal.

Failure to become emotionally mature is a third source of trouble. The emotionally immature child may try to remain a baby in order to get desired attention from his parents. He may use a whining voice in asking for things he wants, or may cry if he fails to have his way. Sulking, quarreling, and temper tantrums are emotionally childish behavior. Being too fussy about food is emotionally immature conduct.

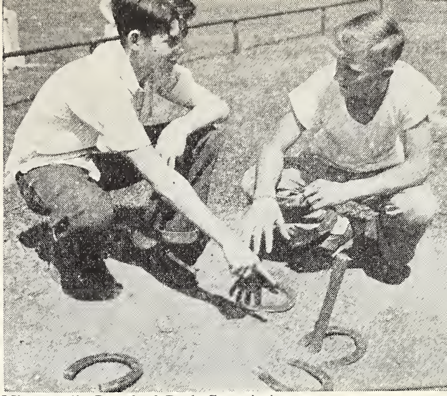
Sometimes people worry because of a sense of guilt. Almost everybody does some things

which they would not want other people to know about. Most people do not worry about such things if they find no ill effects from them. But occasionally a person may worry, and try to punish himself in strange ways for his imagined wrong-doing. Persons who injure themselves in accidents have sometimes been found to suffer from senseless feelings of guilt. Some people punish themselves by not eating enough food.

Mild forms of neurotic behavior may be shown in a great variety of ways. The insecure child or the worrying child may be rowdy, a show-off, or may use foul language in an effort to gain attention. Wearing loud or unsuitable clothing, smoking around school, and boasting are symptoms of lack of confidence for some reason. Extreme shyness is also evidence of lack of self-confidence.

The extremely overconscientious person usually is trying too hard in another way to win approval. While it is highly desirable to do any job well, to waste time on meaningless details is evidence of worry.

There are a few people who, because they feel that they have no friends, find satisfaction in overeating and become fat. Some fat people also feel that not much is expected of fat people, and thus have an excuse for not accomplishing much. Other methods of avoiding facing a problem are forgetting homework or notebooks, or being sick on the day of an examination, or lying about failure to take responsibilities or other unacceptable behavior. A person is not really neurotic unless his emotional condition interferes definitely with his ability to carry on his usual activities.



Minneapolis Board of Park Commissioners

Well-adjusted young people can make and accept decisions. They can also take victory or defeat with poise and self-control.

How is mental illness treated? If you recognize in yourself some of the problems or symptoms which cause emotional disturbance, you need not worry about the danger of becoming mentally ill or going crazy. Most people never do either. After encountering a difficult problem and worrying about it for a short time, they either work out a satisfactory solution or turn their attention to other things and forget about the problem. They do not talk about their fears or worries with their friends, or feel sorry for themselves.

If the problem is not solved by this method, there are people

who are trained to give you help. The school psychologist, home visiting teacher, or counselor may be able to help you state your problem and find a satisfactory solution. If they do not have the time or skill, the family doctor may be able to help, or he may refer you to a doctor called a psychiatrist [sī·kī'*ȧ*·trĭst].

Almost all treatment of mental and emotional illness consists of two parts. The first is to discover the real problem, which may be deeply hidden or denied by the sick person. The second is to help the person face the problem and to find a satisfactory solution to it. There is little use of drugs, hypnotism, or strange looking machines. Long, quiet conversations provide the necessary help to solve problems.

It is especially important for the mentally ill to avoid quacks if they want real help. Fortune tellers, spiritualists, and others are willing to take their money. If you find in advertising any claim to such things as strange powers of the ancients, universal knowledge of the mystic, or cosmic mastership, that is evidence that the advertising is false. Quacks generally misuse scientific words in meaningless ways.

Those who are qualified to help the mentally ill have special training and degrees from recognized universities or medical schools. They do not advertise.

The important thing for the average person to do is to try to solve his own problems, or to obtain qualified help if he is unable to solve them. Continuing worry, fear, or inability to get along on a job or with other people should be considered evidence of need of help.

Exercise

Complete these sentences:

Certain forms of mental illness may be caused by injury to the —1—. A severe form of functional mental illness is called a —2—. A continuing emotional disturbance which interferes with carrying on with normal activities is called a —3—. Mentally healthy people find —4— to their problems, or turn their attention to other ways of obtaining —5—. People who advertise cures for mental difficulties are usually —6—. A doctor who specializes in treatment of emotional difficulties is a —7—. Treatment of emotional difficulties consists of helping the individual understand his —8— and to find some kind of satisfactory —9— for it.

7. Is modern medicine scientific?

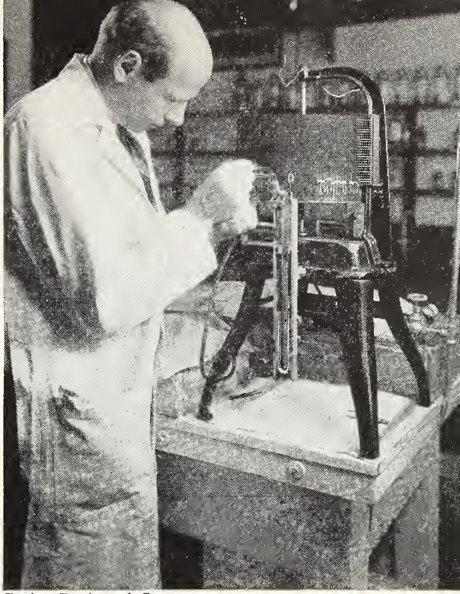
It is apparent that medicine has progressed far along the road toward becoming a science since the days of Hippocrates and Galen. Even so, it is difficult for us to realize even to a slight extent how dependent the modern doctor is upon science for his diagnosis of illnesses and for their treatment.

Does medicine employ experiments? Carefully controlled experiments are common in medical investigation. In one such investigation, a cold vaccine was given to half a large group of col-

lege students. To the other half was given an inoculation of distilled water. At the end of the experiment it was found that the patients receiving the vaccine averaged 1.6 colds per person, while those who thought they had vaccine but did not had 2.1 colds per person. The effect of the vaccine is seen at best to be slight. However, the patients who had had injections of water instead of vaccine thought that they recovered from their colds faster than usual, showing the uselessness of opinion compared with measurement.

In another experiment, several hundred wounds were deliberately infected with two kinds of pus-forming bacteria. Half the wounds were treated with iodine, while the other half were treated with a standard, red-stain antiseptic. Of those treated with iodine, only 24 per cent became infected, but of those treated with the antiseptic all became infected.

Such use of experimental methods is essential. Most medical experiments are not as simple as these described, but are just as well worked out.



Parke, Davis and Company

In this experiment measurements are being made of the effect of pituitary-gland extract upon the blood pressure of a dog. The pressure causes a change in the height of mercury in the U tube and moves a marker which makes a record on the drum.

Does medicine employ measurement? Most people who have had a medical examination have had their blood pressure taken. A cloth bag is wrapped around the arm. Air is pumped through the bag and into a pressure gauge by means of a rubber bulb. At the same time the doctor feels the patient's pulse. When the pressure in the bag becomes high enough, the blood no longer circulates in the arm and the pulse stops beating. Then air is let out of the bag until the pulse can again be felt. The pressure gauge may be made like a barometer but with both tubes open, or it may be an ordinary spring pressure gauge. The figure used to describe blood pressure refers to the difference between the heights of the two columns of mercury expressed in millimeters at the time the pulse returns.

Another type of measurement is made when the number of

Radio Corporation of America

This photograph shows an electron microscope in use. The insert is a single tuberculosis bacillus magnified in the original photograph 45,000 times.

white corpuscles in the blood is counted under a microscope. The presence of more than the usual number of white corpuscles indicates the presence of infection in some part of the body.

What aids to observation are used in medicine? You are familiar with the pictures of broken bones, infected teeth, and of the internal organs made by use of the X ray. As you know, these short waves are able to penetrate flesh easily and bone only slightly. X rays are really shadow pictures. To show the outline of soft tissues, such as the intestines, some means must be found to stop these penetrating rays. Usually a pint or so of a chalky chemical in suspension in water is swallowed. As it passes through the stomach and intestine, its progress can be studied. The condition of the organs can be recognized by a skilled observer if these X-ray pictures are studied. Instead of taking a picture, the rays may be caused to fall upon a screen which glows where the rays strike it. This device, called a fluoroscope, operates upon the same principle that is used in fluorescent lighting.

A number of ingenious devices have been developed for looking into various cavities of the body. Most of them consist of small lights and mirrors placed in tubes which are thrust into the cavity of the chest, lungs, stomach, or other organs. Such foreign objects as coins have been located by use of such a device and then removed. The interior of the stomach may similarly be examined for ulcers (raw sores).

Another device which indirectly shows the condition of the heart is the electro-cardiograph. Contacts are made with the skin by use of salt water, usually on one hand and one leg. The body constantly produces weak electric currents. The current from the body is run through a very sensitive galvanometer. The galvanometer is caused to throw a beam of light upon photographic paper which is rotated upon a drum. The result is a wavy line on the paper. The heart makes five movements which show in the wavy line as five parts of the

wave. If any part of these waves is too strong or too weak, information can be obtained about the condition of the heart.

A similar electrical device is used to show patterns of brain waves.

A device for examining the eye consists of a concave mirror with a hole in the center. The mirror is used to reflect light into the eye, while the examiner looks through the hole in the mirror. In this way it is possible to see the inside of the eyeball. The condition of blood vessels and the tissues of the eye can be observed directly by use of this instrument.

A simple stethoscope consists of a funnel-shaped tube connected to two branching tubes which are held against the ears of the listener. By placing the funnel over the heart or lungs and listening to the breathing and heart beat of the patient, a trained observer can detect unusual conditions. By thumping upon the chest, it is possible to detect the presence of fluids in the chest cavity if any are present. Other stethoscopes contain radio tubes and greatly amplify sounds.

The microscope is used constantly in studying tissues to discover what is not normal.

Are chemical tests used? The most common chemical test used by doctors is for the discovery of sugar in the urine. This condition is found in patients suffering from diabetes. The test is similar to the test for any simple sugar

Parke, Davis and Company

This X-ray photograph shows the large intestine greatly enlarged as the result of a diseased condition. Such a condition may result from lack of sufficient vitamin B in the diet.

—that is, Benedict's solution is boiled with a sample of the urine. Presence of sugar is indicated by a red color.

Chemical tests of the digestive juices are sometimes advisable. Other tests consist of measuring the amount of carbon dioxide a person breathes out during a measured interval of time. The amount of carbon dioxide indicates the rate at which food is being oxidized in the cells. In certain illnesses food is used much faster than is normal, while in other diseases the rate is lower than normal.

Is study of bacteria used? Cases of pneumonia, sore throat, and many other diseases are de-

tected by examination of bacteria under a microscope. The usual procedure in checking sore throat is to collect bacteria from the throat on a cotton swab, which is then immediately sealed in a tube and taken to a laboratory. At the laboratory the swab is brought into contact with a sterile culture medium. The culture is put into a warm incubator for a few hours to obtain bacteria for examination. If no dangerous bacteria are found, the report is negative. If they are found, medical treatment is begun.

The doctor knows, when he has made a proper diagnosis, whether he should start treatment or whether the patient will recover without aid. Doctors know because of their familiarity with disease how to recognize many illnesses as soon as they see the patient. You must not expect every medical call to result in trying out every experimental device known to science. Yet it is comforting to know that there are many ways of using scientific methods to protect us from serious illness.

DEMONSTRATION: HOW IS PRESSURE OF A GAS MEASURED?

What to use: Glass tubing, rubber tubing, mercury, burner, metric ruler, funnel, rubber bands.

What to do: Make a U-shaped glass tube about 15 inches long, with the arms about 1½ inches apart. Fill the tube about one-third full of mercury by use of the funnel and a rubber connector.

Attach the manometer tube you have made to the ruler in an upright position.

Connect a piece of *sterile* glass tubing used for a mouthpiece to one end of the manometer tube, and blow into it. Let another pupil read the *difference* in the level of mercury in the two arms.

What was observed: Can all pupils blow with equal force? How many pounds per square inch does your reading correspond to?

What was learned: How does this demonstration relate to blood-pressure measurement?

Exercise

Complete these sentences:

A safe antiseptic for wounds is —1—. The blood-pressure gauge contains —2—. When one is infected, the number of —3— in the blood increases. X rays are used to throw a shadow on a screen called a —4—. The screen changes X rays to visible —5— rays. The weak current from heart beats is measured by a sensitive —6—. A gelatin plate upon which bacteria are grown is called a —7—. Sugar in the urine indicates —8—. Bacteria are placed in an —9— to make them grow faster.

8. *What health information is dependable?*

There are many unfounded beliefs which may lead to acts which affect our health. Some of these beliefs are leftovers from the days of unscientific medicine, some are delibertaely created by

advertisers, and some are the result of faulty application of sound scientific discoveries.

Do you need special foods? You have read many times that you should eat some particular food to be healthy. As a matter of fact, for a person past babyhood, there is not a single food in the whole world which is indispensable. Some foods do, as you know, provide a greater variety of essential food materials than do others. But every essential food material is found in a great variety of foods. The Asiatic who eats his diet of fish, rough rice, and vegetables is about as healthy as a person in the United States who eats overprocessed and much more expensive foods.

There is no special virtue in any food. While orange juice, grape juice, milk, lemons, meat, and whole grains are excellent foods, none is so essential that sickness results from not using one or more of them. Many foods advertised as health foods are actually difficult to digest, lacking flavor, and much more expensive in proportion to the calories, vitamins, minerals, and proteins they contain than are everyday foods. People who use "health foods" are often neurotic.

Food fads are recommended for various supposed reasons. One is to give greater charm because of improved health, beauty, or vitality. Food is necessary for these things, but no one food is much better than another

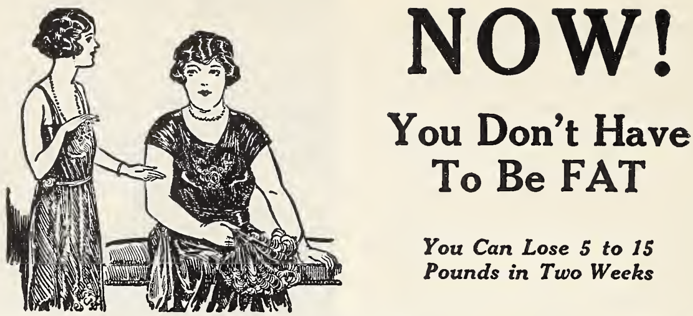
Parke, Davis and Company

The strength of a vitamin preparation is being tested by study of bones of test rats. The microscope shows how much lime the bones contain, compared with bones of rats fed a standard vitamin diet.

for producing these effects. In fact, a balanced diet of many common foods is better than a limited diet of any kind, no matter how excellent the foods may be.

Special diets or drugs for reducing weight are sometimes recommended by newspaper writers, radio speakers, and other unqualified persons. The only right way to reduce weight is to reduce the intake of calories, and the only way to do it safely is to do it slowly while eating foods to make an adequate diet for health.

Is use of laxatives desirable? The most profitable source of income from patent medicines, next to the beauty preparations' racket, is that of selling laxatives.



Many years ago advertisements like this appeared frequently in newspapers and magazines. Today this ad looks funny, not only because advertising has improved but because use of some dangerous drugs is regulated by law.

Few people need laxatives to produce normal elimination of wastes. Laxatives upset the normal processes of the digestive system by one of three methods. Oils hurry foods along the digestive tract faster than the digestive juices can act on them. A mineral-oil salad dressing on a green salad hurries the food along so fast that the body cannot absorb the vitamins from the salad. Salts acting by osmosis withdraw water from the digestive tract and prevent the absorption of food. Certain drugs stimulate or irritate the digestive tract in various ways, hurrying the materials along at an unnatural speed.

Most people can have normal elimination merely by eating a balanced diet including fruits and vegetables, by forming regular habits, and by drinking reasonable amounts of water.

Contrary to popular belief, exercise seems to have no effect on elimination. Use of bran and other harsh roughage is definitely injurious and would probably be discontinued if advertising did not keep its use before the people.

Laxatives are especially dangerous to one suffering from an attack of appendicitis, for the irritation of the intestine may cause the appendix to burst, throwing infection into the lining of the body cavity. This infection may cause death. Never take a laxative for a stomachache.

How can we select good medical care? There are many unfounded beliefs about the efficiency of so-called methods of healing. Any reasonable person can decide for himself which systems are not founded on true scientific procedure.

You know many of the procedures depended upon by doctors of scientific medicine. Such a doctor is familiar with the use of scientific instruments and methods and has studied most diseases which people may have. When a patient comes to such a

[*cont'd on p. 302*]

UNFOUNDED BELIEFS	*EXPLANATION*
Kidney disease is the cause of most backaches.	Backaches are oftenest caused by poor posture, poorly fitted shoes, or flat feet.
A drunk person is not easily injured by falling.	Drunkenness is a major factor in causing deaths by falls.
Playing violent games makes one healthy.	Only the healthy can play violent games.
We dig our graves with our teeth (by overeating).	As many Americans are undernourished as are overweight.
Cold baths prevent colds and make you healthy.	Bathing has little relation to health.
Outdoor living will prevent tuberculosis.	Many tuberculosis patients are outdoor workers.
A clean tooth never decays.	Ordinary methods do not clean teeth.
Shaving makes hair grow.	People shave because hair grows.
A healthy skin depends upon use of cosmetics.	Soap and water provide all the care a normal skin needs.
Pimples can be cured by use of cosmetics or by eating yeast.	Many cases of pimples can be cured by scrubbing with soapsuds three times a day.
One should take medicine to prevent acid stomach.	The stomach is normally acid.
Salt and meat cause high blood pressure.	Salt and meat are necessary in a balanced diet.

UNFOUNDED BELIEFS	EXPLANATION
1) One should sleep with the windows open. 2) Night air is dangerous.	We should sleep in a warm, well-ventilated room, but warmth is as important as air circulation.
Many people are cured by miracles.	The mentally ill may sometimes suddenly abandon the "act" of illness.
One can cure himself of most illnesses.	He who hath himself for a doctor hath a fool for a patient.
All outdoor air is pure.	Air above cities contains smoke, dust, and fumes, reducing the value of sunlight.
One needs a yearly sunburn.	Sunburn is often dangerous.
The best way to lose weight is to exercise.	Exercise improves the appetite and may cause gain in weight.
If a sick person fights his sickness, he will recover.	The ability to fight depends upon the amount of vitality left.
Most people need a special diet to remain healthy.	Most people can eat almost any kind of food that is fit to eat.
Tight hatbands cause baldness.	Baldness is the result of inheritance.

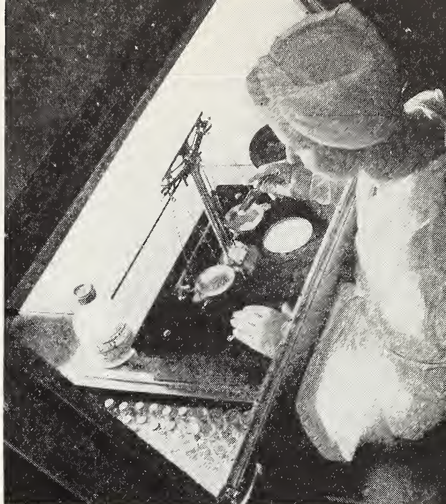
doctor, the doctor immediately makes a diagnosis of the illness by use of his skill and experience. He tries to learn all he can about his patient. Then, when he has found the cause of the disease, he fits treatment to the disease and to the patient. For example, there are many causes of sore throat, and treatment which will produce an immediate cure of one kind may be useless for another. A scientific doctor knows what treatment to use. If the illness is one from which the patient will recover by natural means, the doctor makes the patient comfortable and awaits the natural

cure. If no cure for the disease is known, the doctor makes every attempt to aid body defenses against disease.

Unscientific medicine, on the other hand, does not attempt to discover a different cure for each disease. Instead, most such systems depend upon one type of treatment for all diseases. For example, every patient may be treated with ultraviolet light, or pressure may be exerted upon the feet or spine or other parts of the body in a supposed attempt to cure illness. Any doctor who has only one system of treatment for all diseases is a quack—a fake who pretends skill he does not have. Such doctors are especially pleased to see a patient with a disease from which he will recover naturally, for the doctor then can apply his treatment and claim credit for the cure. But when the patient has a fatal illness, the quack doctor rarely claims responsibility for the death.

Selection of good medical care is of great importance. Many of the people in this country have no medical care at all.

Why are unfounded beliefs untrue? In the table on pages 301 and 302 are several unfounded beliefs, with an explanation of what is considered to be the true situation. You should be able to add to the list yourself.



Merck and Company, Inc.

Purity of medicine is protected carefully. Small bottles are filled with accurately weighed amounts of penicillin in a sealed case. The rubber gloves are built into sealed openings. Ultraviolet light in the case further protects purity.

Exercise

Complete these sentences:

—1— food is absolutely necessary for health. The way to reduce weight, if it is necessary, is to reduce intake of —2—. Mineral oil prevents absorption of —3—. Use of laxatives in an attack of —4— may cause death. —5— medicine depends upon one treatment for all illnesses. People who are cured by miracles are usually —6— ill. One should not play football unless he is —7—. Sunburn is often —8—. Most baldness is a result of —9—.

9. Do good habits protect health?

As boys and girls strive for a mature attitude toward life, it is natural and necessary that they question and examine their childhood knowledge. Some information and habits needed by

U. S. Public Health Service

If you have visited your dentist twice a year since you were as small as this lad, if you have watched your diet carefully to insure enough milk and vegetables, and if you have brushed your teeth regularly, the chances are that as an adult you will have sound teeth.

small children are not adequate for adults. In the process of retesting the value of their knowledge, many young persons do not obtain enough evidence to justify the conclusions they may reach.

In regard to health habits, you may occasionally see an athlete smoking, an apparently healthy grown-up drinking alcohol, or an attractive woman who apparently does not eat recommended foods. You may have stayed up late at night, become wet and chilled, or thrown a temper tantrum without any apparent ill effects. The information needed for sound conclusions cannot be obtained from one case or in a short period of time. Because the body is fairly capable of adjusting to abuse, damage may not become apparent for some time. The damage done by poorly fitted shoes may result in backaches several years later. The tension produced by prolonged fear or worry may produce rheumatism in late middle age. The damage caused by diving into cold water may reduce ability to hear several years later.

Does fatigue injure the health? There is a difference between healthful tiredness and fatigue. When a boy plays football on the playground until he is ready to sit down and rest he is in a physical condition different from that

of a team player who lies exhausted on the ground after the game, unwilling to move. In order for a person to make any strenuous effort, such as playing football, the system of ductless glands pours its hormones (activity-regulating chemical) into the bloodstream. The hormone produced in the adrenal glands in particular stimulates body tension and prepares the body for action. The body does not function without some stimulation from hormones. But an oversupply of any particular hormone is harmful. The adrenal hormone overstimulates the heart, and is an important factor in producing high blood pressure. Fatigue also overloads body tissues with waste products, and may damage the kidneys. The longer the condition of fatigue lasts, the more likely is the damage to be severe.

The effects of physical fatigue may be reduced by long continued training which produces good physical condition. But the training, if overdone, can in itself produce severe fatigue. Overtrained athletes do not perform well.

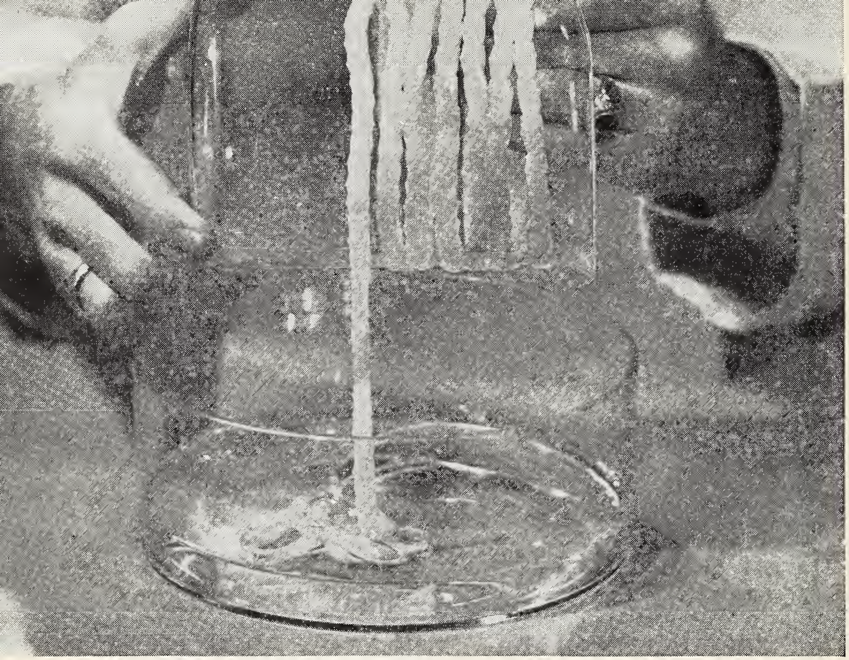
Fatigue can be produced in many ways other than by physical exertion. A girl who stays out for a social activity until one or two o'clock in the morning may be more fatigued than she would be after playing a strenuous basketball game. Continuing loss of sleep, particularly in adolescence, leads to chronic fatigue which produces loss of interest in normal activities. Fatigue reduces resistance to almost all disease, but particularly to colds, tuberculosis, and pneumonia.

Every boy and girl knows how to avoid excessive fatigue. Nine hours sleep at your age, rest after strenuous play, and limiting your activities to what you can do without strain will prevent dangerous fatigue.

Is malnutrition really dangerous? With the best supply of food available to any people in the world, many people in the United States are severely undernourished. More than half the women of this country suffer from anemia to some extent, and many to the extent that their activities are severely handicapped by lack of reserve energy. Women need more iron in their diets in proportion to their weight than men do, and tend to eat less food containing iron than men do. Many people fail to obtain the amounts of vitamins necessary to maintain really good health. Boys and girls are often underweight, nervous, or restless because of what has been called hidden hunger. You should remember, too, that fat people are often undernourished because they eat too much carbohydrate and not enough protein, vitamin, and mineral foods.

Some skin blemishes so annoying to adolescents will clear up if a balanced diet replaces a faulty diet.

Malnutrition of mothers of young babies, both before and after the birth of the baby, is an important cause of sickness, de-



Ward's Natural Science Establishment, Inc.

A tapeworm is being prepared in the laboratory for study. Tapeworm larvae are found in some kinds of meat. Can you think of a good reason for eating only meat that has been cooked?

formity, or death of babies. It has been found that test animals fed poor diets are incapable of producing healthy young. The same effect is possible and not uncommon among people.

Malnutrition reduces resistance to fatigue and the ill effects which it produces. Malnutrition need not be very severe to reduce resistance to colds, tuberculosis, and other dangerous diseases.

Does cold affect the health? It is a common experience to become wet or chilled and to have a cold within a short time. The chilling does not produce the cold, but it does lower body resistance. The cold virus overcomes the lowered body defenses. Effects of polio are much more serious if the victim is chilled at the time of becoming infected. Exposure to cold water is known to affect the hearing of divers and long distance swimmers. Continued chilling takes so much of the available bodily energy supply that it increases the rate at which fatigue sets in.

It is not necessary to wear heavy clothing all the time to prevent chilling. Only when it is really cold or raining is protection necessary. Rubbers or overshoes, a warm, heavy coat, a rain-

coat, a warm cap or scarf, gloves or mittens, and protection for the legs are all the extra clothing that is needed.

These garments must be worn when needed to be of value. It is not sissy to keep healthy. You might let your show-off friends have the colds, while you have the fun which healthy people can have.

Does worry affect the health? The effects of worry or fear or any emotional upset, even including extreme happiness, can produce about the same effects as fatigue. The ductless glands which control emotional behavior are stimulated by every upset. High blood pressure, stomach ulcers, headaches, and digestive upsets result from continued emotional strains. Loss of appetite may lead to malnutrition.

What can you do to be healthy? You already know the general rules of health. You know what you should eat, how long you should sleep, how to care for your teeth, how to avoid fatigue, how to keep clean, what clothing to select and when to wear it, and how to fit into a social group. The important thing is to do these things.

The benefits of playing physically active games, under safe conditions, can hardly be overemphasized for teen-age boys and girls. Physical activity stimulates the appetite and encourages eating of good foods. It uses up chemicals and blood sugar which may be released in the body by emotionally exciting situations.

Minneapolis Board of Park Commissioners

Learning to swim with a group develops not only a muscular and well-rounded body but a well-rounded personality as well. It increases social skill and poise to know how to take part in activities.

It helps to eliminate fatigue products from the muscles and other organs of the body. It builds healthy bodies. The benefits of being with other happy boys and girls will show in improved mental health and social poise. No matter how busy you think you are, an hour or two a day is needed for play.

It is not necessary nor generally desirable to try to be a member of a school team in order to play. Swimming, skating, tennis, wrestling, basketball, volleyball, softball, baseball, horseshoes, badminton, touch football, and many other games do not require great physical strength or endurance if played with others of your own size and age. Farm children can walk, ride horses, climb, and do many things unavailable to city children.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: COLD, FATIGUE, MALNUTRITION, WORRY. In each col-

umn write the names of five avoidable conditions or situations which might cause the undesirable results named at the top of the columns.

10. How can we apply first aid to save lives?

While it is unwise for anybody but a doctor to treat ordinary illness, it is essential that everyone should know what to do to save life in case of serious accident. The most common accidents are automobile accidents, falls, burns, drowning, poisoning, snake bite, and electric shock. In treating the victim of an accident, it is just as important to know what not do as it is to know what to do.

What should we do in case of an automobile accident? The automobile accident often causes broken bones, serious cuts, and severe internal injuries. One thing not to do is to move the patient to an upright position. If the victim is moved, a broken rib may puncture the heart or lungs, a broken vertebra may sever the spinal cord, or a splintered bone may cut an artery.

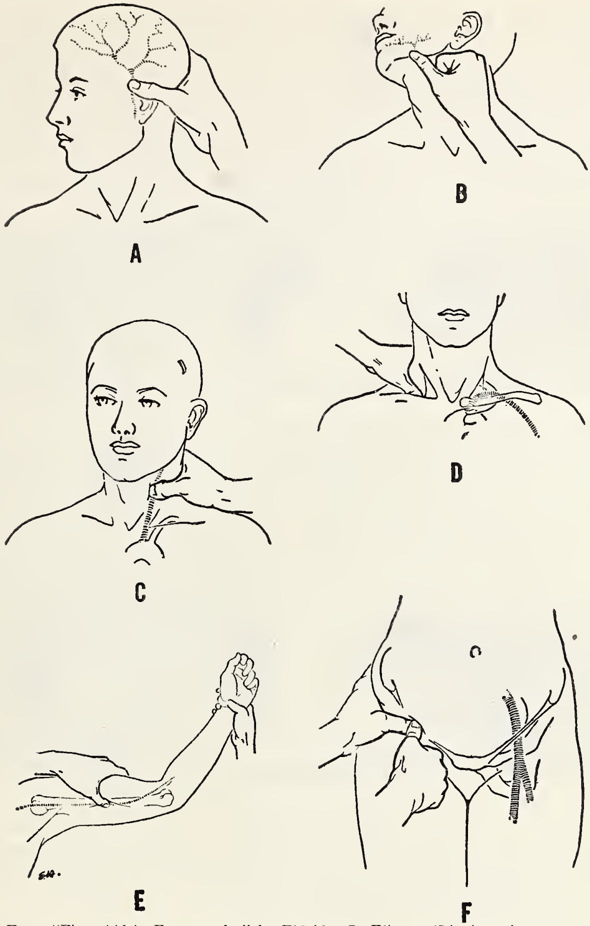
If there is severe bleeding, immediate treatment is necessary. The major arteries of the body come near enough to the surface at certain areas, called pressure points, that pressure properly applied will stop circulation. To stop bleeding in areas supplied by these arteries, pressure is applied upon these points by pressing them firmly with the fingers. If the bleeding is from an arm or leg, pressure may be applied by means of a tourniquet [to͝or′ nĭ·kĕt]. A tourniquet is a broad band of cloth which is tied loosely around the limb. Above the pressure point a solid object, such as a stone or potato, is put into the tourniquet, and on the opposite side of the limb a stick is slipped beneath the band and twisted until bleeding stops. (*A tourniquet must be loosened every 10 minutes to avoid blood poisoning!!*)

In extreme cases lives have been saved by grasping the cut ends of blood vessels and holding them shut with the fingers.

If the patient is not bleeding

The tourniquet on the arm is made of two boards bound with strips of cloth. One board presses an artery against the bone. The tourniquet on the leg is tightened by twisting the stick.

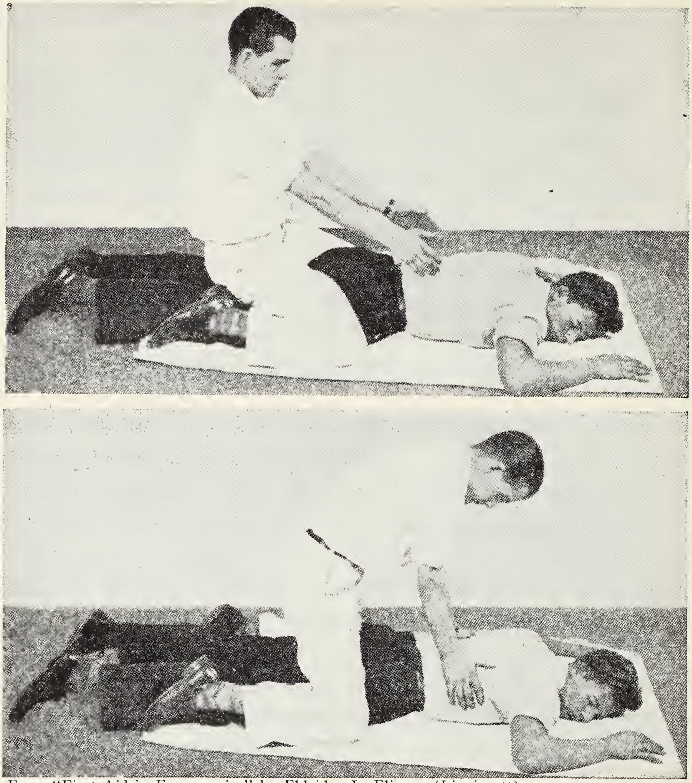
From "First Aid in Emergencies" by Eldridge L. Eliason (Lippincott)



From "First Aid in Emergencies" by Eldridge L. Eliason (Lippincott)

Bleeding may be stopped by applying pressure directly to the arteries supplying blood to the bleeding area. Pressure applied as shown at A stops bleeding from the scalp; as at B, from the face; as at C, from the neck; as at D, from the high shoulder and arm; as at E, from the lower arm; and as at F, from the leg. You should memorize these pressure points in order to know how to stop bleeding with the hands or with a tourniquet.

noticeably, the limbs may be gently straightened and the victim laid gently on his back. But if you have any reason to suspect that an arm or leg or the back is broken, don't under any circumstances try to straighten that part of the body. (*Don't try to lift the*



From "First Aid in Emergencies" by Eldridge L. Eliason (Lippincott)

A procedure for applying artificial respiration is illustrated. Note particularly how the hands are placed, with the little fingers just touching the lowest ribs. This operator would work still more effectively if he were sitting nearer the patient's feet and had not extended his thumbs.

patient.) Station someone on the highway to slow traffic to prevent further accidents, and call the highway or city police and the ambulance.

If it is absolutely necessary to move a patient who has a broken bone, the bone must first be held firm with splints. A splint is a series of rods, sticks, or boards bound around the limb with strips of cloth. Never use cords. The splints are tied in place so firmly that the limb cannot bend. Yet the binding must not shut off circulation. Splints should be padded for comfort.

When the splints are applied and bleeding is stopped, a stretcher may then be slipped beneath the patient's body. The stretcher may be made of buttoned

coats with strong sticks slipped through them, or it may be a board or a piece of metal. It must be rigid enough to keep the patient's body from sagging. Three men can lift a person by thrusting their arms beneath his body, holding it level. It is better to put the patient flat on the bottom of a truck than in a passenger automobile. Never, under any conditions, set the patient upright in the seat until it has been determined that no ribs or vertebrae have been broken. Get the help of a doctor or first-aid specialist as soon as possible.

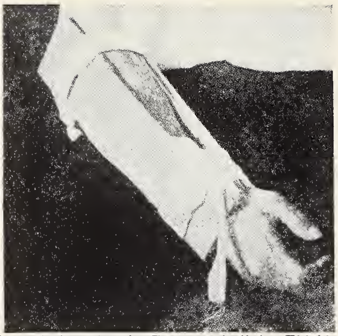
What should be done to treat burns? If the victim's clothes are afire, smother the fire by rolling him on the ground or by covering the fire with a rug, blanket, or woolen coat. It may be necessary to use force to do this. If the victim stands up, he may breathe flame and die. The best home treatment of burns which break the skin is use of a solution of one tablespoonful of soda in a pint of sterile water. A sterile bandage is dipped into this solution and spread on the burned area. The bandage should be kept warm and moist until medical aid arrives. If other materials are available in a first-aid kit, follow directions exactly. For burns which do not break the skin, use of a cooling ointment or clean mineral or vegetable oil is sufficient.

Never put cotton or a dry bandage on a burn which breaks the skin. Don't pull burned cloth from the wound. Don't apply iodine. Don't use any bandage that is not sterile.

What treatment is required for drowning and electric shock? In the case of a person who has lost consciousness from either drowning or electric shock, the first requirement is to re-establish breathing. It may be necessary to remove the victim from a live wire. Do not touch him until the current has been shut off or grounded on each side of him.

Lay the victim face down. Remove gum, tobacco, false teeth, or any other object from the mouth. Be sure that the tongue does not clog the throat. Bend one of the patient's arms to serve as a pillow, and rest his head sidewise upon it. Stretch the other arm above his head. Then sit astride the body. Put your hands where the little finger just touches the lowest rib. Then with your arms stiff, lean forward slowly until your weight presses upon the patient. *Immediately* swing backward, releasing the pressure.

To obtain the correct rhythm, chant, "Out goes the bad air, and in comes the good." As you say, "Out goes the bad air," press forward. Then take your hands away quickly. As you say, "and in comes the good," sit back. The operation should be completed each five seconds. Normal breathing should occur after a few minutes, but sometimes patients have been restored to life only after hours of effort. Artificial respiration, as the process is called, should be continued until



From "First Aid in Emergencies" by Eldridge L. Eliason (Lippincott)

Some torn cloth and two boards have been used to make splints for a broken forearm. The arm should be placed in a sling after being put in the splints.

the patient recovers, unless his muscles become stiffened by death.

After normal breathing is restored, treat the patient for shock.

What is the treatment for shock? Following any severe injury, the patient is likely to suffer shock. The symptoms are chilling, poor circulation, a pale or bluish color of the skin, cold perspiration, and a rapid and weak pulse. The patient should lie down, and be kept warm by use of hot-water bottles, blankets, newspapers, or any practical materials. The head should be kept below the level of the body. Stimulants are generally not needed, although some people want hot coffee. Whiskey and alcohol are definitely harmful.

What should be done for snake bite? When a poisonous snake strikes, its hollow, needle-like fangs inject poison deep into the wound. Unless the poison is removed or unless its effects are offset by antivenin, the patient will die. The directions for use of antivenin serum are included with the kit, which may be purchased complete.

The poison can be washed from the wound by causing bleeding. Since almost all snake bites occur on the arms or legs, poison may be kept out of the blood stream by placing a tourniquet above the wound. Loosen it every 10 minutes. The next step is to cut an X over each fang mark. A clean, sharp knife should be used if possible. Each cut should be one-fourth of an inch deep and half an inch long. Blood should be caused to flow from the cut for half an hour, either by use of any suction device available or by sucking with the mouth. Then treat the patient for shock.

What should come before first aid? First aid is usually required because someone has been thoughtless or careless. Do not ride with a driver who is reckless, careless, intoxicated, or too tired. Do not wrestle in water. Do not swim in deep water without someone near in a boat. Do not use matches, gasoline, alcohol, electricity, or chemicals carelessly. Do not walk in places where there are snakes unless you wear heavy boots. Keep out of weeds if you are barelegged—shorts are not intended for wear in the woods. Don't put your hands in holes, on the ground, or

in weeds where you cannot see. You might find a snake or poison ivy. Do your climbing on safe ladders. Do not stunt or show off.

An injured person frequently is either a fool or a victim of a fool. Even so, we should try to save his life by every possible means.

Exercise

Write a paragraph summarizing this problem, using the following words: shock, artificial respiration, pressure, 12 times a minute, soda, bleeding, pressure points, cut, antivenin, warm, suction, half hour, tourniquet, 10 minutes.

A review of the chapter

Maintaining good health is achieved by efforts in three directions. The medical profession investigates causes of illness and works out methods of controlling them. Among these methods are surgery, vaccination and inoculation, use of drugs, and use of other scientific methods. The individual has the responsibility of maintaining good body condition by eating an adequate diet, by getting enough sleep, by cleanliness, by avoiding contact with sick people, and by forming good health habits in general. The community has the responsibility of providing a pure water supply, inspecting food supplies, providing medical care for those who cannot afford it, and in other ways caring for its citizens.

The relatively great success of modern peoples in preventing great epidemics, as well as avoiding the general suffering from sickness in many forms, depends upon the co-operation of all three agencies: the medical profession, the individual, and the community. None of these can take over the work of the others and hope to succeed.

It is important to keep mentally healthy. If good living habits and good attitudes do not develop mental health, medical aid should be obtained.

We must act only upon sound health information, and not upon unscientific and unfounded popular beliefs. It is important to apply safety rules to daily living until following them becomes a habit.

Word list for study

antiseptic	intoxication	inoculate	spirochete
toxoid	stimulant	neurotic	infectious
antibody	electrocardiograph	malnutrition	protozoa
bacillus	quack	splint	neurosis
insulin	anesthetic	narcotic	psychiatrist
immunity	antitoxin	caffein	ductless gland
specific drug	virus	stethoscope	artificial respiration
psychosis	coccus	vaccine	patent medicine
fatigue	contagious	serum	X ray
tourniquet	white corpuscles	sterile	laxative

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

A. Many diseases are caused by bacteria, viruses, or animals which live within the body.

B. Immunity is acquired when the body overcomes a disease or when antitoxins or antibodies are placed in it.

C. Preventing the spread of germs will prevent infectious diseases.

D. Specific drugs assist the body in overcoming specific diseases.

E. Drugs may upset the normal functioning of the body.

F. Cold, fatigue, and malnutrition prepare the body for disease.

G. Bacteria may be killed before they can cause disease.

H. Mental illness which interferes with normal life activities results from continuing emotional upsets.

List of related ideas

1. A sulfa-type drug cures bubonic plague.
2. Tuberculosis is caused by a bacillus.
3. Kissing a person who has tuberculosis is dangerous.
4. Typhoid fever can be prevented by inoculation.
5. A cut should be treated immediately with iodine.
6. Athlete's foot is caused by a fungus.
7. Quarantine is used to control some contagious diseases.
8. Smallpox is best controlled by vaccination.
9. A stimulant causes the body to use energy faster than it is replaced.
10. The toxin-antitoxin treatment prevents diphtheria.
11. Lister cleaned his surgical instruments with carbolic acid.
12. Every ninth grade pupil needs about nine hour's sleep.
13. The sulfa-type drugs are often effective against coccus type bacteria.
14. Typhoid, cholera, and dysentery are controlled by complete purification of water.
15. Alcohol is used by some people in an attempt to escape their fears.
16. One should never drink water from a roadside stream.
17. Air in hospitals is purified by ultraviolet rays.
18. It is possible to worry oneself sick.
19. Everyone needs a good breakfast.
20. Alcohol lowers resistance to tuberculosis.
21. Patent medicines are not usually taken by the physically ill for long periods of time.
22. Underweight children are more frequently ill than normal.
23. Constant worry may cause a pupil to be a show-off.
24. Special diet fads usually cause harm if followed for long.

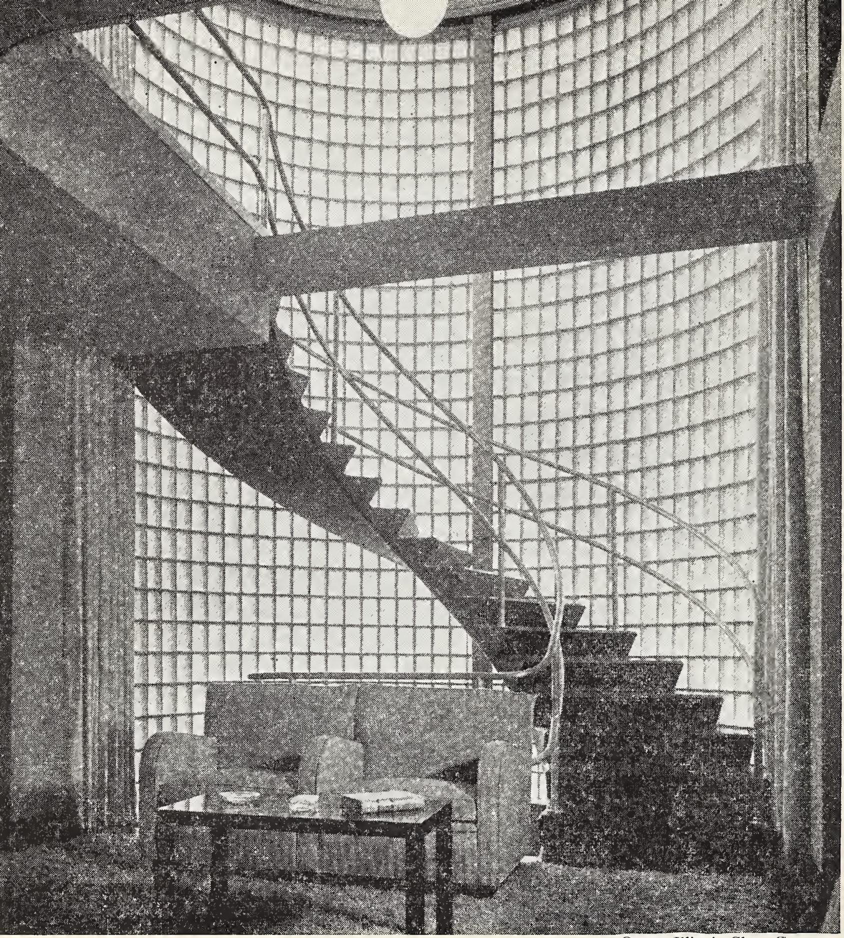
25. Alcohol taken in large amounts will cause unconsciousness.
26. Hookworms in the intestines weaken the whole body.
27. Tuberculosis attacks people who are rundown, underweight, or tired.
28. Ether stops action of nerves and stops pain sensations.
29. One should not put unclean objects in his mouth.
30. When one is becoming ill, chilling makes many diseases worse.
31. Measles may be prevented by using serum from immune people.
32. Diagnosis should be made before any medicine is given.
33. Diphtheria germs attack throat tissues and may cause death.
34. Bandages may be sterilized by baking them.
35. Smoking makes difficulties after an operation more probable.
36. Yellow fever is no longer dangerous where mosquitoes are controlled.
37. You should not shake out a used handkerchief in a public place.
38. Arguments at meals may cause indigestion.
39. Inadequate thiamine intake causes beriberi.
40. Increased adrenal hormone secretion results from nervous tension.

Some things to explain

1. At about the age that many boys go into training for athletics, many girls enter into late-hour social activities. Which is the safer and better life? Why?
2. Why did modern medicine have to await development of the sciences of chemistry, bacteriology, and physics?
3. What is the chief danger in using patent medicines?
4. What are some of the useless methods advertised for reducing weight?
5. In what ways can communicable diseases be controlled better by the community than by the individual?
6. What habits are harmful to health?
7. Of what value are the tests for immunity to certain diseases?

Some good books to read

DeKruif, P. H., *Fight for Life*
Eberle, I., *Modern Medical Discoveries*
Epstein, S. and Epstein, B. W., *Miracles from Microbes*
Fishbein, M., *Common Ailments of Man*
Kallett, A. and Schlink, F. J., *100,000,000 Guinea Pigs*
Montgomery, E. R., *Stories Behind Great Medical Discoveries*
Reidman, S. R., *How Man Discovered His Body*
Silverman, M. M., *Magic in a Silver Bottle*
Sokolov, M. M., *Story of Penicillin*
World Book Encyclopedia
Zinsser, H., *Rats, Lice, and History*



Owens-Illinois Glass Company

UNIT FOUR

LIVING IN A MODERN WORLD

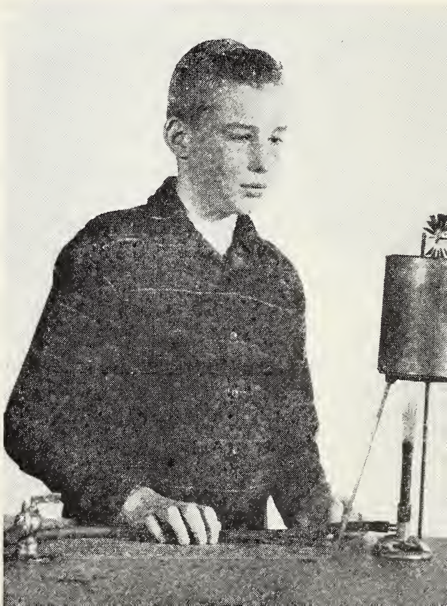
Frank said, "I might as well tell you that it required some skill to construct the model I am going to show you. But it is very simple in principle."

There was a tin sirup pail containing water on the stand over a burner. Frank placed the cover on the pail, and placed the burner beneath it. On the cover was a small paddle wheel mounted on some rods.

Frank continued, "I have some tools at home which made it possible to make this model. The supports are bolts. I drilled holes through the pail cover, and pushed the bolts upward through it. In order to make bearings for the wheel shaft, I ground one side of each bolt flat, and drilled a small, cone-shaped hole in it. I made the shaft by grinding both ends of a nail to points. The paddle wheel I made by cutting a circle very carefully from a tin can with tinsnips, and cut each vane along lines I had carefully measured on the circle of tin. I soldered it to the shaft."

Just then there was a hissing noise from the pail, and the little paddle wheel started to turn rapidly. Frank held the blade of a screw driver between the paddle wheel and the pail cover, and the wheel stopped. When he removed the screw driver, the wheel started turning again.

"You notice that the steam from the boiling water provides the force which turns the wheel. I made a jet hole in the cover in just the right place beneath one side of the wheel to let the steam strike the vanes with good force. This little wheel demonstrates the principle of the turbine."



CHAPTER

7

Machines of Modern Living

Our modern way of living depends so much upon machines that we are inclined to take them for granted without much thought. We can operate many machines with almost no knowledge of how they work, and we receive the benefits of machines of which we know nothing. The food we eat would cost more and would not be so plentiful if we did not have many special kinds of machines on farms. Our clothing is made by machines. We do many of the more difficult home tasks—cleaning the floor, washing clothing, mixing foods, and ironing—with machines. We put the food in a mechanical refrigerator to keep it fresh. Our food is delivered in trucks.

There are machines which do specialized work of making shoes, of blowing insects from crops, of pressing metal into special shapes, and of punching holes in sheets of postage stamps. There are machines which are used to make machines.

Machines, then, are part of the complex modern world. They have made it possible for people to produce in large amounts many of the things which make life easier and more comfortable. They have reduced the drudgery of living and have made it possible to shorten the working day, both in industry and in the home, so that almost all people have leisure time. Machines have made it possible for us to live in comfortable houses.

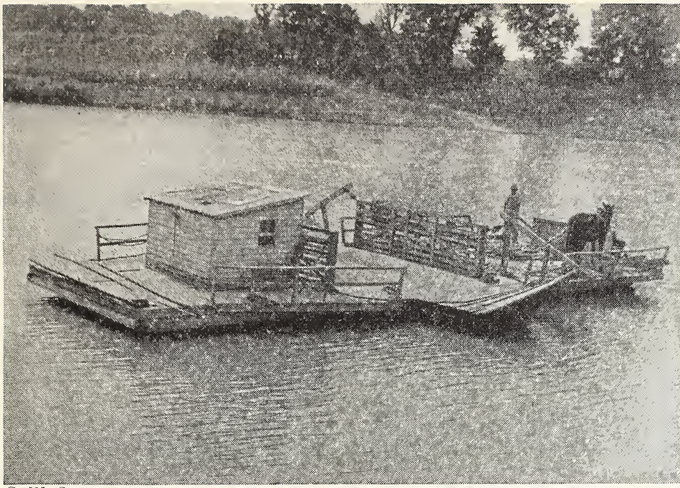
Some activities to do

1. Visit a small, modern machine shop and learn how machines are used to produce goods.

2. Visit a large factory where mass-production methods are employed and where much of the work is done by automatic machines.

3. Learn thoroughly the operation of every machine in your home. Study the booklets that explain the care and operation of the machines.

4. Find in a reference book an explanation of the differential pulley.



G. W. Sturm

This old ferry boat actually has a one-horsepower motor. The horse walks around in a circle, turning the crank which operates a paddle wheel.

Construct one of a large and a small spool, properly mounted and supported.

5. Make a collection of tools, toys, and common devices, and make an exhibit of common simple machines. Use care in mounting or displaying your collection, and bring it to school.

6. Make a steelyard balance. You should be able to use it to weigh objects with fair accuracy.

7. Make models of one or more of the following machines: *a*) A turbine, using tubing, a shoe-polish can, and metal blades held in a cork. *b*) A pump, using a glass tube, a stopper, and inner-tube rubber for valves. *c*) A water wheel, using either wood from apple boxes or metal from cans. *d*) A windmill, using metal, wood, and wire, mounted on a wooden frame. Use coat-hanger wire for shafts. *e*) A windmill to operate a lift pump. Construct the windmill so carefully that when you set it before a fan, the pump will pump water.

8. Make a cross-section model of a steam engine, using heavy cardboard or plywood. Make it in such a way that the slide valve and piston will move.

9. Using a bottle, cork, wire, and boards, make a model piston, cylinder, connecting rod, and crankshaft.

10. Visit a factory, and observe as many machines as you can.

11. Make a model crane with a mechanical toy building set, and work out its mechanical advantage.

12. Make a study of bearings. Collect as many as you can from old machines.

Some subjects for reports

1. The first machines which produced the industrial revolution

2. The effect of machines on employment and the working day

3. Special machines for special uses (several reports)

4. Archimedes experiments with machines

5. Eli Whitney and the beginning of mass production

6. Attempts to make perpetual-motion machines

7. Machines used to make machines

8. Rockets ancient and modern

9. Some machine used in agriculture not explained in this problem. The ensilage cutter, the binder, the apple washer and polisher, the farm water system, the cotton picker, or the grain cleaner are suggested.

10. Materials used in grinding wheels. Look up carborundum, sandpapers, emery, and pumice.

1. *How do machines make our work easier?*

There are many machines which are used to make our work easier. Some of these machines apply forces other than the force of our muscles. Other machines apply forces to such materials as liquids and gases which we cannot handle with ordinary tools.

Some machines make it possible for us to use the great forces of nature: steam, exploding gasoline, running water, or wind. A force is a push or a pull. It results when energy is applied in such a way that it tends to produce motion. A force has two characteristics which can be measured. These are amount and direction. The amount of force may be measured in several ways, but the simplest is to compare all forces with the force of gravity, using the pound for comparison. That is, we will compare the downward force of gravity as exerted on a pound of matter with other forces we wish to measure. The easiest way to do this is to use a spring balance to measure forces.

The direction of a force may be just as important as its amount. The direction of a force is the direction in which it tends to move something, and not the direction from which it comes. If two boys are pushing on the same side of a heavy door they can open it, but if both push equally hard on opposite sides their forces add up to zero, and the door does not move. Methods of adding forces acting in different directions are often difficult.

Machines which make it possible for us to avoid using our muscles may properly be called labor-saving machines, but not work-saving machines. We can use them to get work done without using our muscles as mere sources of power for machines. All these machines provide a moving surface against which the force operates to produce motion.

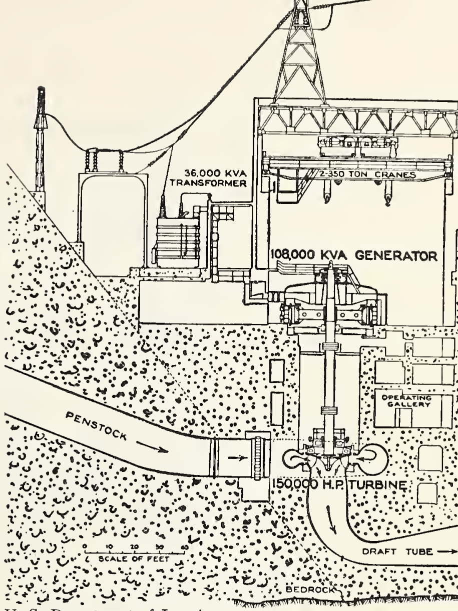
What machines have moving blades? The windmill, the water wheel, and the turbine are machines which provide a means of applying force to do work.

The windmill is made up of a number of strips of wood or

metal, called vanes, against which the wind exerts pressure. The force of the wind is greater on the part of the vane toward the wind than is the pressure of the air on the back part of the vane. Because the vane is set at an angle, it serves as an inclined plane. The wind slides past the vanes, and the vane whirls around the central shaft to which it is attached. The vane also acts as a lever.

Windmills are most frequently used for pumping water. A very successful windmill made of propeller blades is used to turn a small dynamo for farm electric plants.

The paddle wheel used in water-power plants operates upon the same principle as the windmill. Since the water flows against only one side of the wheel, it is possible to set the blades at right angles to the direction of flow of the water. Because water slides off the ends and sides of the blades, much of its force is lost. The water may fall from above and pass over the wheel, as in the case of the overshot wheel; or it may flow underneath, as in the case of the undershot wheel. In the Pelton wheel, water is shot from a nozzle against cup-shaped blades. Because of the greater efficiency of the cups in taking energy from the water, and because of the inertia (the tendency of an object in motion to remain in motion and of an object at rest to remain at rest) of the fast-moving water, this wheel delivers more power than do other wheels.

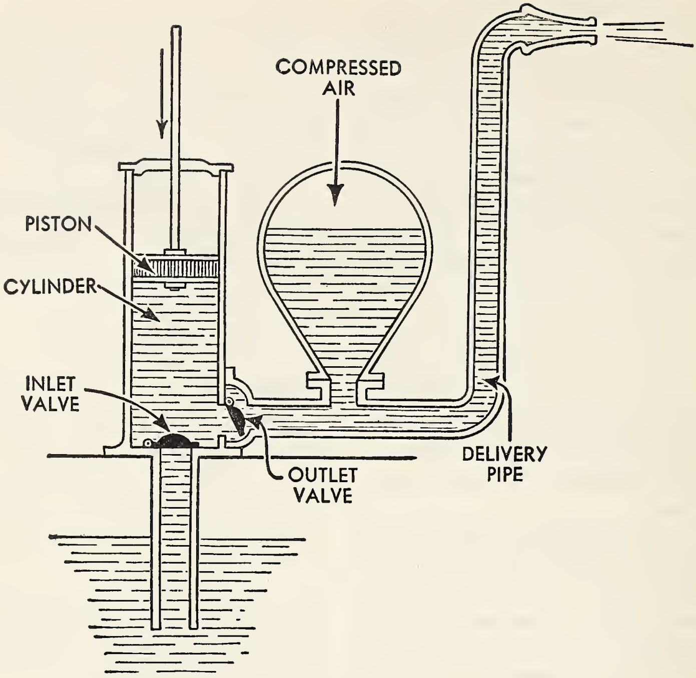


U. S. Department of Interior

This diagram shows how water power is transformed into electrical power at Grand Coulee Dam by one of the largest electric generators in the world. Trace the energy changes from water in the penstock to the power line.

All the revolving-blade machines have the advantage that when they are set in motion their inertia carries them along until the force is used to overcome some resistance other than their own inertia.

Water wheels are used less today than formerly. The turbine is used to turn dynamos in practically all those electric generating plants which depend upon running water for power. At Niagara Falls, at Norris Dam in Tennessee, and at the Grand Coulee Dam in Washington the force of falling water is used to generate electricity.

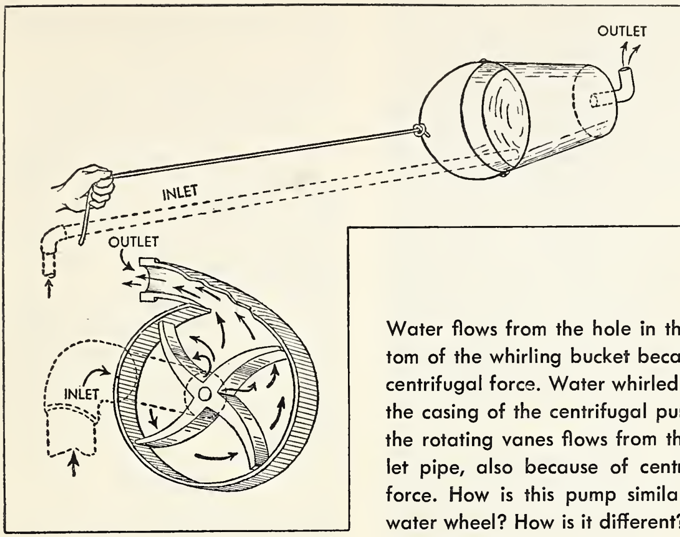


The force pump consists of a cylinder, the moving piston, and two valves. Air pressure forces water into the cylinder on the upstroke of the piston. The water is forced through the outlet on the downstroke. Explain how the valves operate on each stroke.

What are the piston-and-cylinder machines? There are several piston-and-cylinder machines—the gasoline engine, the steam engine, and the gun being in common use. In each case the high pressure required to exert a force upon the moving piston comes from an expanding gas. When a solid or liquid changes to gas, its volume increases tremendously. The compressed gas is hot and expands with great force. For example, the common gun has a barrel, which serves as a cylinder, and a bullet, which acts as a piston. The burning powder forms a gas which exerts pressure on the bullet.

The piston of an engine travels back and forth inside the cylinder. It must stop completely at the end of each stroke. It thus loses the inertia of motion and acquires the inertia of a body at rest. This type of machine is more wasteful of energy than is a turbine.

All machines which use power from gases or liquids depend in



Water flows from the hole in the bottom of the whirling bucket because of centrifugal force. Water whirled inside the casing of the centrifugal pump by the rotating vanes flows from the outlet pipe, also because of centrifugal force. How is this pump similar to a water wheel? How is it different?

their operation upon the principle that when pressures upon opposite sides of an object are unequal, the object tends to move toward the lower pressure.

How do machines move liquids? Because of their nature, liquids are difficult to lift. To lift water by hand, it must be held in a dipper or pail. It is tedious to dip water from a well.

In order to lift water by exerting force upon it, it is necessary to enclose the water in a container from which it cannot escape until the force acts upon it. Water can be lifted in this way by pumps. One of the most successful pumps is the ordinary force pump shown in the diagram. The cylinder serves as a container. When the piston moves upward, the pressure inside the cylinder is reduced, and air pressure in the well forces the water into the pump. The valve at the bottom of the cylinder is opened by the flow of the water. When the piston moves down, the water forces the bottom valve to close and opens the outlet valve. This operation is repeated over and over, as long as the piston is moved up and down.

A most interesting pump is the centrifugal [sĕn·trĭf′ů·găl] pump. Centrifugal force is a kind of inertia. A body in motion tends to move in a straight line. When it is held in place by a container or a string, a rotating object tends to fly out of its circular direction. The outward push or pull exerted by the rotating object is called centrifugal force.

If you whirl a pail of water that has a hole in the bottom around your head on a rope, the water shoots out from it with more force than if the pail is not

whirled. The centrifugal pump employs this principle—that is, it whirls the water around rapidly until it gains considerable force, and then carries it to an opening. The water runs forcibly from the opening.

One kind of centrifugal pump contains revolving blades, like the blades of a turbine. Another kind contains a screw which forces water along. These pumps are used in most city water systems, in irrigation systems, and in the automobile cooling system.

Can machines save work? Work is a force acting through a distance. No matter what force is used, the amount of work done in moving a given resistance a given distance is always the same. Thus it makes no difference whether a tank is filled with water by hand or by use of a pump and gasoline engine. The work done equals the weight of the water multiplied by the height to which it is lifted. How it is lifted makes no difference in the amount of work done. A machine cannot save work, but it can save our muscles.

DEMONSTRATION: HOW DO MODEL MACHINES OPERATE?

What to use: Model force pump, model water wheel, model turbine, model windmill.

What to do: Set up and operate the model machines.

What was observed: Describe briefly the operation of each machine.

What was learned: Classify the parts of each machine as simple machines. State how force was applied to each cause.

Exercise

Complete these sentences:

Machines cannot save —1—, but can apply —2— to save us the need of using our muscles. Force can be applied to revolving —3— or to a —4— operating within a cylinder. Force of —5— water or the force of expanding —6— may be applied to do work. The outward push or pull of a rotating body is called —7—. This force is a special form of —8—. The most efficient machine for applying water power is the —9—.

2. Why do we use machines?

We know that there are few kinds of work that can be done without proper tools. Tools are so important that it is doubtful that civilization could have developed without their use. The simplest tools—the club, the knife, the axe, and the bow—are known to most primitive peoples. In our own time we know how impossible it is to build houses, repair automobiles, or cultivate the garden without the necessary tools. Tools are made up of simple machines.

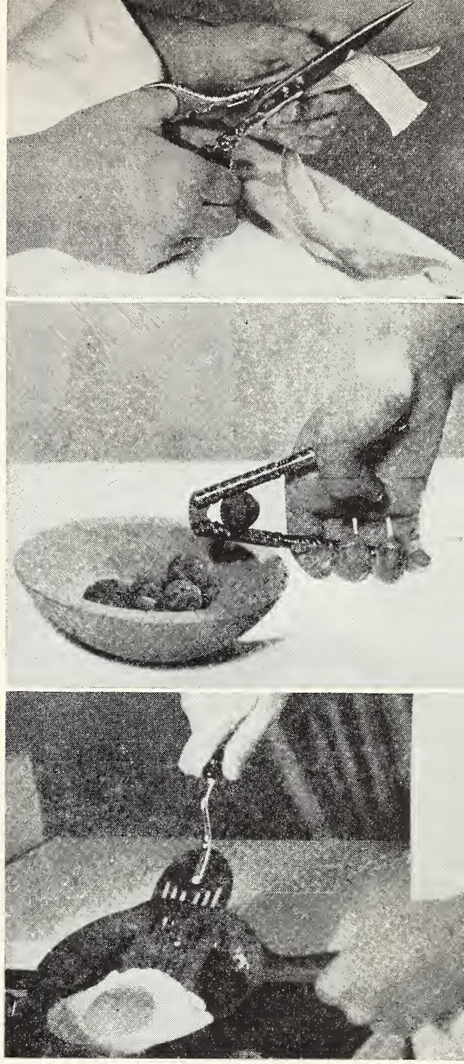
What are simple machines? A machine may be defined as any device which may be used to apply force to good advantage. Suppose you wish to drive a nail. You can hardly do this with your bare hand. Yet with a hammer you

can do it easily. The hammer provides a handle which increases the force of your swing and a hard surface which strikes against the nail. While you have no more strength when you use a hammer, you do apply force to much better advantage than you could do without it.

Objects do not ordinarily move easily because there are opposing forces which we call *resistance*. One force which resists movement is gravity. When an object lies on the ground, it cannot be lifted until it is picked up against the pull of the gravity of the earth. Another common resistance is *friction*. If you have ever tried to open a stuck drawer or to unscrew the cover of a pickle bottle, you know what friction is. A third form of resistance is *inertia*. Inertia is the tendency of an object at rest to remain at rest until enough energy has been added to start it in motion. You know from experience that if you have a heavy object to move you must start it slowly because of its resistance to motion. Nor is it easy to stop a moving object quickly.

Machines apply forces to overcome resistances. If we are successful in overcoming resistance and moving something, then we say we are doing *work*. Unless the object moves, no work is done. Work is defined as a force acting through a distance. Machines apply force to do work.

How do machines change forces? If you wish to move a heavy stone lying on the ground,



These common household tools are really levers. The hand in each case supplies the force which the machine applies to good advantage.

you do not give up because the stone weighs more than you can lift. You obtain an iron rod, called a crowbar, and dig under

These common tools are also simple machines. For how many tools can you state the most common use? How many simple machines make up all these tools?

the stone until you can slip the end of the bar beneath the stone. Then you put a small stone beneath the crowbar to support it, and throw your weight upon the bar. Unless the stone weighs several times more than you do, it will move. Thus you can use a small force to move the heavy stone. By repeatedly moving the supporting stone and the bar, you can roll the larger stone a considerable distance.

Of course you push the end of the bar through a much greater distance than you move the stone. Thus if you multiply your force four times by use of the crowbar, you move the stone only one-fourth as far as you move the end of the bar on which you push.

Similiarly, we use a can opener when we wish to cut metal. While it is possible to cut metal with a knife, it is difficult. The handle of the common can opener multiplies the force, although we must move it up and down many times to cut around the can.

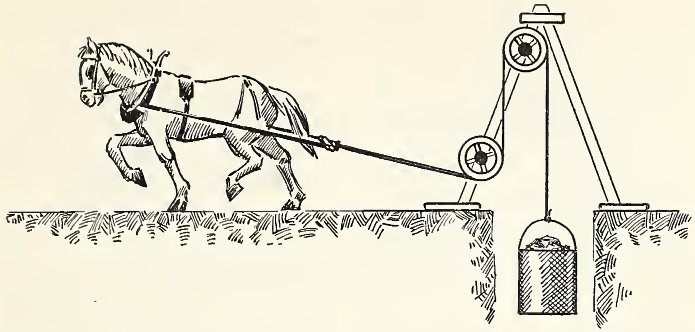
Scientists state the relation between the force and the distance as a law, thus: The moving force times the distance it moves equals the resisting force times the distance it moves. This idea may be stated more briefly:

$$\textbf{force} \times \textbf{distance} = \textbf{resistance} \times \textbf{distance} \ \textit{or} \ \textbf{fd} = \textbf{rd}$$

Since a force times a distance is work, we may express the same idea by saying that we get only as much work out as we put in.

There are many times when we wish to move some small object through a considerable distance. In this case we must have much more force than we need to move the object. For example, you can move dust along the floor by kneeling down and using a hand brush. Each stroke moves the dust a small distance. By using a broom, you can increase the distance of each stroke because the handle of the broom increases the reach of the arm.

Shovels, pitchforks, and rakes similarly increase the distance we



The use of pulleys makes it possible for the horse to walk in one direction while exerting force in another. The resistance is the force of gravity. Is there any way you can measure the amount of work the horse is doing?

can move comparatively small resistances or loads with relatively large forces.

The fishpole is another machine which increases the distance through which we apply the force. When we catch a fish, we wish to remove it from the water quickly before it can escape. The fishpole increases the distance we can move the fish in a short time. If we catch a five-pound fish, we may have to exert a force of 20 to 40 pounds to remove it from the water, however. What we gain in distance we lose in force.

There are many times when we do not wish to increase our force, or gain distance, but still we cannot easily reach the object we want to move. For example, it is easier to lower a flag by means of a rope passing over a pulley than to climb the flagpole and carry the flag down.

When we draw water from a country well with a bucket, it is necessary to pull upward on the rope. It is easier to apply the same amount of force pulling downward on a rope passing over a pulley. The famous old oaken bucket was hung from a pulley. This type of machine gives an advantage in changing the direction through which the force is applied.

Many tools are similarly used to move things not easily reached. Tongs, forceps, and holders are such tools.

What is mechanical advantage? As you know, scientists prefer to use numbers instead of words when it is possible. Mechanical advantage may be defined as the *number* of times a machine multiplies the force put into it. If we are able to use a force of five pounds on the handle of a claw hammer to pull a nail which has a resistance of 40 pounds, we say the hammer gives a mechanical advantage of eight ($5 \times 8 = 40$).

If we use a force of 14 pounds to lift a two-pound fish on the

end of a fishpole, the mechanical advantage of the fishpole is one-seventh ($14 \times 1/7 = 2$). Mechanical advantage may be either a whole number or a fraction.

DEMONSTRATION: HOW DOES A MACHINE MULTIPLY A FORCE?

What to use: Meter stick, balance support, clamps, weights of 100, 200, 500, and 1000 grams.

What to do: Support the meter stick at the center, causing it to balance. At the 45 cm. mark, hang the 1000-gram weight. Consider this weight the resistance. Hang each of the other weights on the opposite end of the balance in turn, in such a position that each weight balances the 1000-gram weight. Measure the distance from the center of the balance to each weight.

What was observed: Make a list of the distances and the weights. Multiply each of the four weights by the distance it hung from the center. Compare the results.

What was learned: Is there any comparison between the force and the distance and the resistance and the distance on the balance? What is the comparison, if it exists?

Exercise

Complete these sentences:

A —1— is a device for applying —2— advantageously. A force is a push or a pull which tends to overcome a —3— to produce motion. Common resistances to motion are —4—, —5—, and —6—. —7— is a force times a distance. —8— is the number of times a machine multiplies the force put into it. Machines permit use of a small —9— to overcome a large resistance, or they permit use of a large force to move a small object through a greater —10—. A machine also makes it possible to change the —11— in which the force acts.

3. *What are the simple machines?*

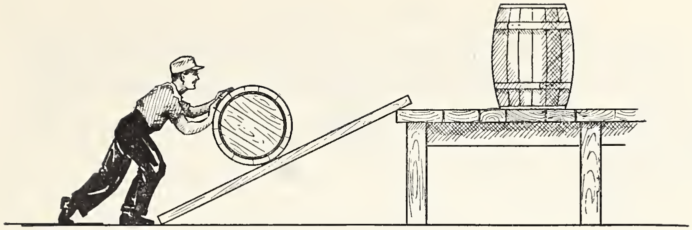
A careful study of the many kinds of tools shows that they can be divided into two large groups: those which are levers and those which are inclined planes. Many of the common tools are combinations of levers and inclined planes.

A lever is a rigid bar which turns around a point called the fulcrum. The crowbar, the claw hammer, and the wheelbarrow are common levers. An inclined plane is a sloping surface. A knife blade is an inclined plane—that is, when the blade is laid flat on the table, the top surface slopes upward.

It is perhaps easier to understand these tools if the two groups are further classified until there are six groups of simple machines. The levers may be divided into ordinary levers, pulleys, and wheels and axles. The inclined planes include wedges and screws.

Every common tool may be classified as one or more of the six simple machines.

What are the inclined plane machines? The simplest in-



One of the simple machines is the inclined plane. Use of the board increases the distance through which the barrel must be rolled but reduces the amount of force needed.

clined plane is the skid which is used to roll barrels into a truck. It consists merely of sloping boards. The common doorstop is another inclined plane. All sloping roads are inclined planes. So are sloping ladders and stairs.

The mechanical advantage of an inclined plane is obtained by dividing the length of the incline by its height. That is, a board eight feet long, supported on a platform four feet high, has a mechanical advantage of two. A force of 100 pounds could thus be used to roll a 200-pound barrel up the incline.

All the ordinary sharp-edged and pointed tools are wedges. The knife blade, the chisel, the needle, the can-opener blade, scissor blades, and razors are wedges. These tools depend not only upon the amount of slope of their sides but also upon the sharpness of their edges to be effective. A dull knife has spots along the blade which have no slope at all—that is, the plane is not really inclined, but is parallel to the surface of the object cut.

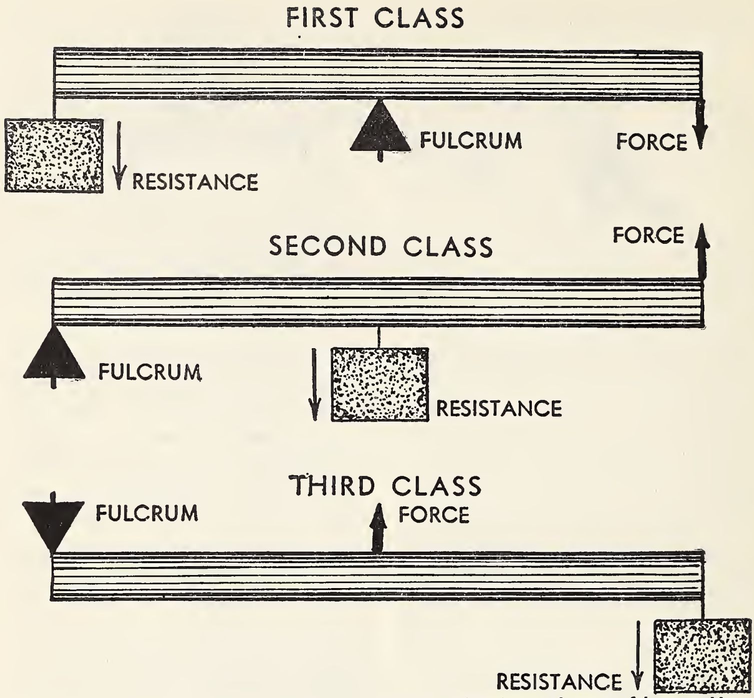
The wedge is used in splitting wood to force the pieces of wood apart. In this use, the resistance is great, and a small force applied to the hammer must be used many times to split the log. The wedge used in shaving hair encounters very little resistance, and the problem is one of having the blade sharp enough to cut through the hair.

Many common tools are screws. The fruit-jar lid, the carpenter's bit, the wood screw, some clamps, and some automobile jacks are screws. Monkey wrenches, bolts, and electric-light bulbs have screw threads.

A screw is an inclined plane which is turned around a central rod. The *pitch* of a screw is found by counting the number of threads per inch of length. The more threads, the greater is the mechanical advantage of the screw.

The screw wastes much energy in overcoming friction, for the threads slide against the wood, bolt, or other material in which the screw is turned.

What are the levers? The levers are the commonest of all machines. They form the handles of



Explain the locations of all the parts of each of the three classes of levers. How do they differ?

most tools, make up the means of carrying force from one part of a machine to another, and serve as balances, teeters, and piano keys.

Levers are so common that they are divided into three classes, according to the position of the force, the fulcrum, and the resistance. If the fulcrum is between the force and resistance, the lever belongs to the first class. In a second-class lever the resistance is between the fulcrum and force. In the third-class lever the force is between the fulcrum and resistance.

Some common *first-class levers* are the teeter board, pliers, scissors, the claw hammer, and the pump handle.

Common *second-class levers* are the wheelbarrow, the electric-light key, the common can-opener handle, the nut cracker, the monkey wrench, the carpenter's brace, the handle of the pencil sharpener and egg beater, and the door key.

Third-class levers include the human arm; handles of brooms, shovels, and hoes; laboratory forceps; sugar tongs; and fishpoles.

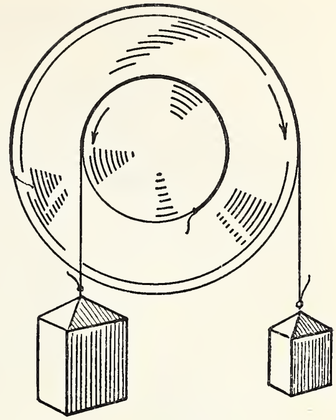
The mechanical advantage of levers may be found by measuring the length of the arms of the lever. The distance from the

force to the fulcrum is called the force arm; the distance from the resistance to the fulcrum is called the resistance arm. The mechanical advantage of a lever equals the length of the force arm divided by the length of the resistance arm.

The mechanical advantage of a first-class lever may be either more or less than one, but as this lever is generally used, the mechanical advantage is greater than one. The mechanical advantage of a second-class lever is always more than one. The mechanical advantage of a third-class lever is always less than one.

The wheel and axle is really a second-class lever. The steering wheel of an automobile, the dial knobs of the radio, the steam radiator valve handle, and the screw-driver handle are wheels and axles. Some of the less familiar uses of the wheel and axle are in the ship's capstan, which is used to lift the anchor, and in the windlass, which lifts loads from holes by winding a rope around a drum.

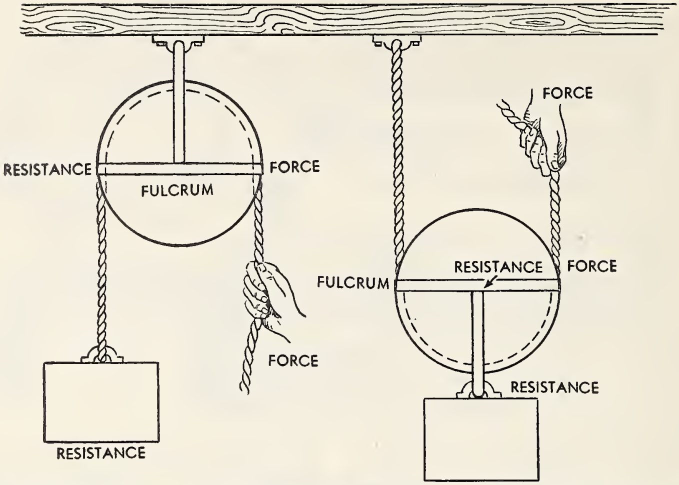
You may have trouble thinking of a pulley as a lever, unless you think of the spokes of the wheel as being levers. Pulleys may be arranged in a variety of ways, as shown in the diagram on page 332. One fixed pulley has only one cord supporting the weight and has a mechanical advantage of one. One movable pulley has two cords supporting the weight and has a mechanical advantage of two. When more than one pulley is used, the mechanical advantage may be found by counting the number of cords supporting the weight.



The wheel and axle is a lever. Explain the location of the fulcrum, the force, and the resistance.

Pulleys are used for a number of purposes. The sash weight is suspended over a pulley. Lifeboats are commonly lowered by use of a combination of pulleys called a block and tackle. The pulley wheels are mounted in the block, and the pulleys and ropes make up the tackle. Pulleys are used on the farm to stretch wires for fences; to lift small loads, such as carcasses of animals which have been killed for meat; and to put hay in the barn.

Another kind of pulley system has a belt passing from one wheel to another. This arrangement is used to carry power from engines to saws, grinders, and other machines. Thus pulleys may be used to change either amount or direction of force.



The single fixed pulley is a first-class lever. You can observe this fact by considering that two spokes of the pulley wheel make up the lever. Similarly, you may observe that the single movable pulley is a second-class lever.

DEMONSTRATION: WHAT IS THE MECHANICAL ADVANTAGE OF THE INCLINED PLANE?

What to use: Board about 6″ × 4′, small cart, cord, weights, spring balance, ruler.

What to do: Support one end of the board to form an inclined plane. Measure the length and the height of the board from the level of the table. Put the weights in the cart and pull the cart up the incline with the spring balance. Note the reading. Repeat several times to be sure of the reading. Weigh the cart.

What was observed: Divide the length of the incline by its height. Divide the resistance by the force. Are the results the same? Why?

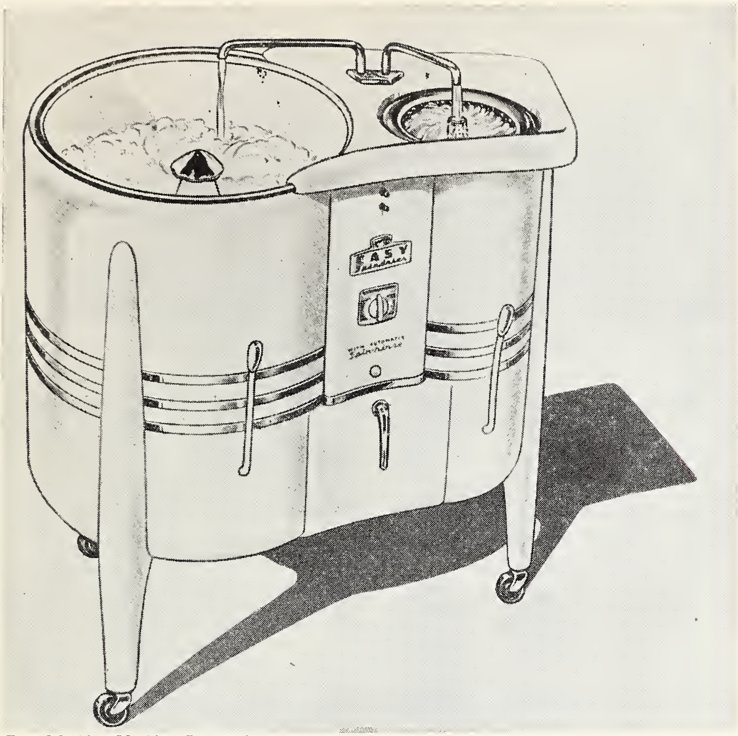
What was learned: What is the mechanical advantage of this particular inclined plane?

Exercise

Make a table by ruling your paper into six columns. Head each column with the name of the simple machines: LEVERS, PULLEYS, WHEELS AND AXLES, INCLINED PLANES, WEDGES, SCREWS. *Divide the column headed* LEVERS *into three parts, heading the parts 1st class, 2nd class, 3rd class. In the correct columns write the names of 25 common tools or machines.*

4. What machines do we use in the home?

Women use more machines in the home than are used in many businesses. The modern home is to a large extent a machine shop.



Easy Washing Machine Corporation

This modern washing machine rinses and dries clothes in a water remover spinning 960 turns a minute. What force acts on the water?

Some of the common household machines are the washing machine, the vacuum cleaner, the electric refrigerator, the electric mixer, the sewing machine, the piano, the ironer, and the clothes drier.

How does the washing machine work? There are several types of washing machines on the market. There are both different kinds of power mechanisms and different types of washers. The commonest type of tub is round and contains a set of modified paddle wheels which agitate the water. After the water has been circulated in a certain direction for a short distance, the direction of the force is reversed by a gear arrangement, and the clothes are swished through the water against the direction of the current. The new current is established just as the direction of movement is again reversed. Another type of washer is made of one tub, perforated on all sides, inside another. This tub is spun around and reversed in direction

at short, regular intervals. In some machines the tubs are whirled in irregular paths inside a second tub.

Power is provided by gasoline engines, electric motors, or by hand-operated cranks.

The wringer-type clothes drier is not safe to operate. One safe type of clothes drier is the spinner which consists of a perforated inner tub that dries the clothes by centrifugal force. Some driers tumble the clothes and have a fan which blows air heated by an electric coil through the clothes.

How does the vacuum cleaner work? There are two types of vacuum cleaners on the market and in general use. One type has a fan and motor which are mounted on wheels, and the complete cleaner is rolled over the rug. The fan reduces air pressure in the nozzle and forces the air under pressure into the dust bag. The dust bag is a closely woven sack with a fleeced inner finish. The fibers filter the dust from the air as it passes through the bag. Some cleaners are equipped with brushes which are rotated by the motor; some have brushes which are rigidly held against the rug; and still others have no brush.

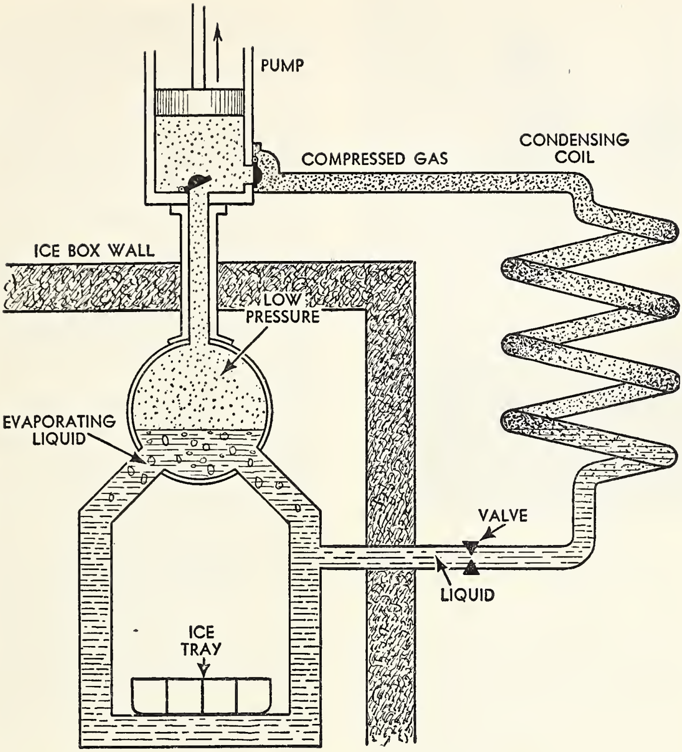
The second type of vacuum cleaner consists of the same parts as the first. However, the motor, fan, and dust bag or air filters are situated in a portable, tanklike container, and are set upon the floor. Extending from the fan there is a long tube to which a nozzle is attached to pick up dust. This type of cleaner is advertised as being lighter to operate than the one in which all the mechanism is moved.

The best models of the two types of vacuum cleaner are equally effective in doing their work. The only way to test a vacuum cleaner is by actual use under standard, laboratory conditions. In tests where dirt was applied to a rug it was found that, by running cleaners 20 minutes over a 9 by 12 rug, good cleaners picked up about three-fourths of the dirt, while poor cleaners picked up less than half.

Electric vacuum cleaners are dangerous, in that they frequently become worn, and either the motor or cord may become grounded. This situation offers a serious shock hazard. No other electrical machine is so likely to be handled with one hand while touching with the other hand a grounded connection, such as a radiator or water pipe.

The vacuum cleaner is the only satisfactory device for cleaning rugs. Fewer bacteria enter the air and less dirt is left in the rug when a vacuum cleaner is used than when any other cleaning method is used. Because some of the sand is removed, the rug wears better.

How do the refrigerator and freezer work? The ordinary icebox is not a machine. It is merely an insulated container. The electric refrigerator or deep freezer is a combination of several common devices. One, of course, is an electric motor which fur-



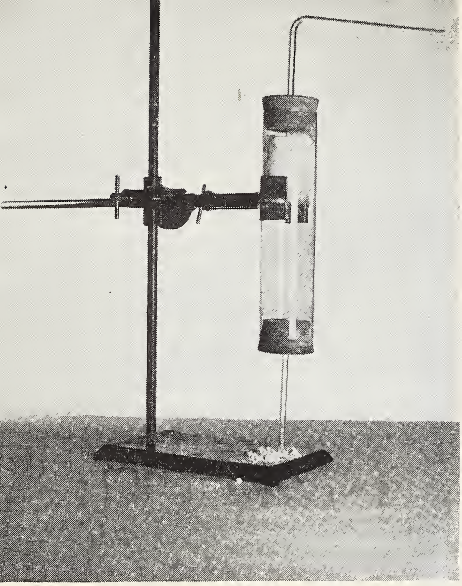
The electric refrigerator consists essentially of a pump and two coils. In the coil inside the box low pressure causes a liquid to boil. In the coil outside the box high pressure causes a gas to condense. Heat is transferred from the box in the process.

nishes power. Another is some type of force pump. A freezer and refrigerator differ in temperatures maintained and in arrangement of storage space.

Anyone who can remember how cooling and heating affect evaporation of liquids can understand how the refrigerator works.

The actual cooling takes place in the cooling unit, which is a coil of pipe. Inside the coil a liquid is permitted to flow and evaporate. When liquids evaporate, heat is absorbed. The heat absorbed comes from the inside of the refrigerator and the articles in it. The pressure in the coil is kept relatively low by a pump which constantly pumps out the gas as it is formed. The low pressure causes the liquid to evaporate rapidly and speeds up the cooling process.

The pump collects the gas from the coil and compresses it.



This apparatus may be used to illustrate the principle of the vacuum cleaner.

The gas becomes warmer as it is compressed. The coil containing the warm gas under pressure is cooled, either by a stream of water or by air moving through radiating vanes on the coil. As the gas is compressed and cooled, it gives off enough heat that it changes to a liquid. The pump and coil for cooling the compressed gas are located outside the refrigerator. The heat which was originally inside the refrigerator is carried to the outside.

When the liquid is cooled, it trickles through the valve into the cooling coil inside the refrigerator and is again changed into a gas by absorbing heat from the interior of the box. Either of the two types of pumps are used, the piston or rotary force pump.

The coil inside the box becomes covered with ice, as moisture from the food condenses on the cold coils. The ice formed is an insulator. To get rid of the coating of ice, it is necessary to shut off the current once a week and let the box warm up enough to melt off the ice. A pan is set under the freezing unit to catch the falling water and ice. This process is called defrosting and is done automatically in newer refrigerators.

The construction of the freezer or icebox is of utmost importance for the proper operation of the refrigerator. The walls must be waterproof, easily cleaned, and strong. Between the walls insulation is placed to exclude heat. The door is fitted tightly with rubber gaskets to seal all cracks. The air circulates in the icebox, falling below the cooling coil and rising along the outside walls.

The commercial ice machine, although not a household device, is essentially a big electric refrigerator unit. It is used to freeze ice cubes much larger than those frozen in the home refrigerator, but the principle of freezing is the same. The ice blocks are generally frozen in tanks. The tanks are in a vat of salt water, through which the freezing coil pipes run to chill the salt water or brine. Much of the ice delivered in our homes is made by ice machines. Since one coil is warmed as the other is cooled, the warm coil can be used to heat water or even a building.

DEMONSTRATION: HOW DO THE VACUUM CLEANER AND REFRIGERATOR WORK?

What to use: Air pump, lamp chimney, stoppers to fit, glass tubing, flour, bell jar, plate, watch glass, cork, ether.

What to do: Set up the lamp chimney as shown in the picture. With the mouth or air pump withdraw air sharply from the upper tube.

Set up the air pump to exhaust the bell jar. On the plate put a cork. Wet it, and put the watch glass on the wet cork. Fill the watch glass with ether, and cover with the bell jar. Pump air from the bell jar until the ether boils away. Quickly examine the watch glass and cork. (*Do not have a flame or an electric motor in operation near the ether.*)

What was observed: Describe what you saw in each part of the demonstration.

What was learned: Explain why the two observed results took place.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: air pressure, fan, pump, evaporation, dust bag, cooling, condensation, gives off heat, shock, ice, defrost, insulation, motor, force pump.

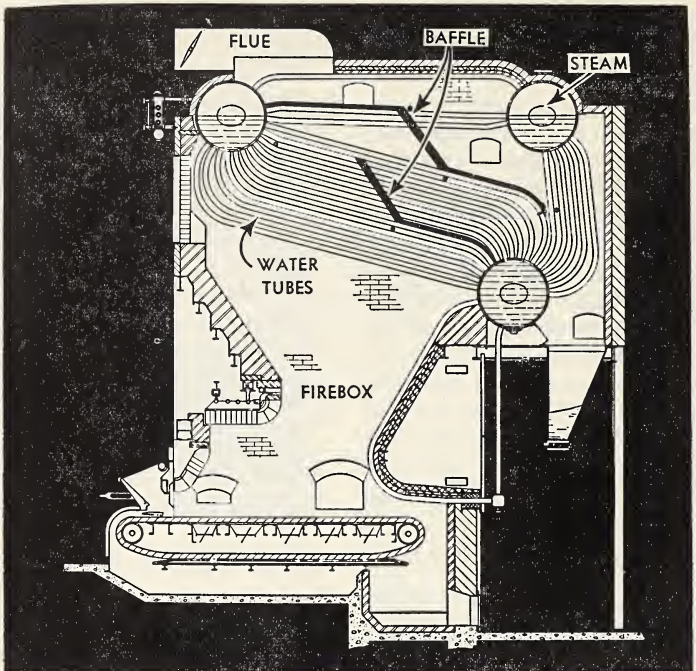
Also draw in your notebook a diagram of the refrigerator machinery.

5. How does the steam engine work?

An engine is a device which transforms heat to mechanical energy. The efficiency of any engine depends upon how much of the total heat available in the fuel is converted to work.

Engines obtain their energy from the expansion of gases. When a gas expands it cools—that is, it gives off heat. The amount of heat given off in the engine determines how much work the engine can do. Engines are much less than 100 per cent efficient because heat is lost in several different ways. In burning the fuel in the furnace or engine some heat always escapes through the smokestack or exhaust. Some unburned fuel is also lost. Some heat is lost by radiation, from the pipes, from the boiler, or from the engine itself. No engine can take all the heat from the gases, and as a result some heat is always lost in the exhaust or outlet pipes. Friction of the moving parts of the engine reduces the amount of useful energy available.

The steam engine is a fairly simple engine. It has few moving parts, and these are large and strong. It does not have the complex timing devices or the many pistons and cylinders of the gasoline engine. It is simpler to operate and repair than other engines. The ordinary steam engine is not very efficient, for it uses only about 10 per cent of the energy in the coal to do work. Even so, ordinary steam engines are cheap to operate, for it is said that a modern freight locomotive can haul a ton of freight a mile with a handful of coal and a glass of water.



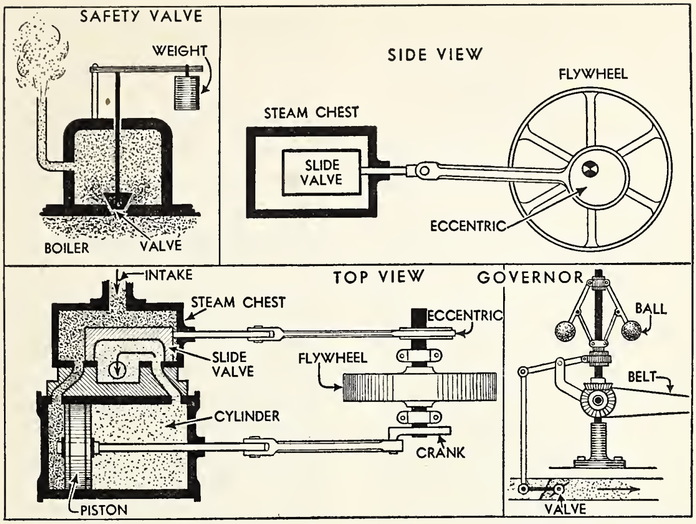
Union Iron Works

Steam is generated in a boiler. The flames pass around the baffles and through the water tubes to get all the heat from the fire that is possible. The object of the pipes is to increase the heating surface.

How is steam generated? Steam is generated in a boiler. The usual commercial boiler is heated by a stoker-fired, or blower-fired, coal burning furnace. Natural gas and uranium are also used to heat water. Tubes of water run through the flames to absorb maximum heat. The greater the amount of surface exposed to the hot gases, the more efficient is the heating. Some small boilers have fire tubes—that is, the hot gases go through tubes which are surrounded by water.

When water changes to steam, it increases in volume 1600 to 1700 times at normal air pressure. Steam boilers produce high pressures. For use with small turbines, it is common to employ a steam pressure of 400 pounds per square inch. To attain this pressure, the water and steam are heated to 450 degrees Fahrenheit. Steam which is so hot and under such great pressure is completely dry and acts as a gas.

How does the steam engine work? The steam engine was not invented by any one person,



Can you tell in what parts of the diagrams the steam is under high pressure? Study these diagrams until you can explain the function of each part that is named.

but the man who did most toward its development was James Watt. He improved an engine, invented by Newcomen in 1705, by adding better valves and a governor. The steam engine is largely responsible for the industrial revolution which brought about our machine-type civilization.

The operation of the steam engine is comparatively simple. The steam is led from the boiler through a pipe to a regulating valve called a throttle. When the throttle is open, steam enters the steam chest, a boxlike structure on the engine. From the steam chest there are two openings into the cylinder, one entering at each end. These openings are called ports. Inside the steam chest is a slide valve, which is in such a position that one or the other of the ports is always closed. Other types of valves are used in steam engines, also.

The steam under pressure enters the intake and passes through one of the ports to the cylinder. When the pressure of the steam is exerted upon the piston, the piston moves, operating a crank attached to a shaft. The shaft is turned. As the shaft is turned, an eccentric [a wheel off center] turns in such a way that it changes the position of the slide valve. Steam is then admitted to the other end of the cylinder, and the piston moves back. The steam in the cylinder behind the piston escapes through the port covered by the slide valve and passes out of the engine through the exhaust.

The purpose of the slide valve is to permit the steam to enter the ports alternately and to permit the steam enclosed in the cylinder to escape when it has done its work.

The double or triple expansion engine consists of a series of two or three cylinders, side by side, each larger than the one before it. Steam under great pressure is led to the first cylinder. After the steam has been used in the first cylinder, it is led to a second cylinder and may in turn be led into a third cylinder. Steam is finally condensed and returned to the boiler by a pump. Such engines are more efficient than the single expansion engine.

The flywheel is used to give the engine a constant speed. The flywheel has a heavy rim. When the piston reaches the end of the cylinder, the steam exerts no pressure for an instant. The inertia of the flywheel carries the piston beyond this dead point and insures the desired even speed. To start an engine, it is sometimes necessary to turn the flywheel to get the piston into a center position.

There are two devices which increase the safety of a steam engine. One is a safety valve. The safety valve in the diagram is the simplest possible kind. Often a spring is used instead of a weight. When the pressure of the steam in the boiler becomes sufficient to force the valve open, the pressure is reduced as the steam escapes or "pops off." The safety valve prevents accumulation of pressure sufficient to explode the boiler.

The governor regulates the speed of the engine. It is located upon the intake pipe and controls the amount of steam that enters the steam chest. It consists of two balls, as shown in the diagram, which are turned by a belt connected to the shaft on which the flywheel turns. The faster the balls turn, the more they are separated by centrifugal force. As they separate, they pull a lever which partially closes the steam valve. As the valve closes, less steam enters, the speed of the engine decreases slightly, and the balls fall to a lower position, causing the valve to open again.

What are the uses of steam engines? Many of the nation's fastest passenger trains, and almost all the ordinary trains, are pulled by steam locomotives. The locomotive has two engines, one on each side, so placed that one is always in starting position. Many factories, sawmills, electrical generating plants, ice plants, and pumping stations depend upon the steam engine for power.

DEMONSTRATION: HOW DO STEAM ENGINES WORK?

What to use: Toy steam engine, cross-section model of engine, model governor.

What to do: Operate the toys and models, observing carefully how each part does its work.

What was observed: Compare your

observations with the description in the text of the operation of large engines and turbines.

What was learned: State the principles upon which these engines opèrate.

Exercise

Make a drawing of the piston, cylinder, slide valve, and steam chest, as shown in the diagram on page 339, but with the piston and slide valve at the opposite ends of their strokes.

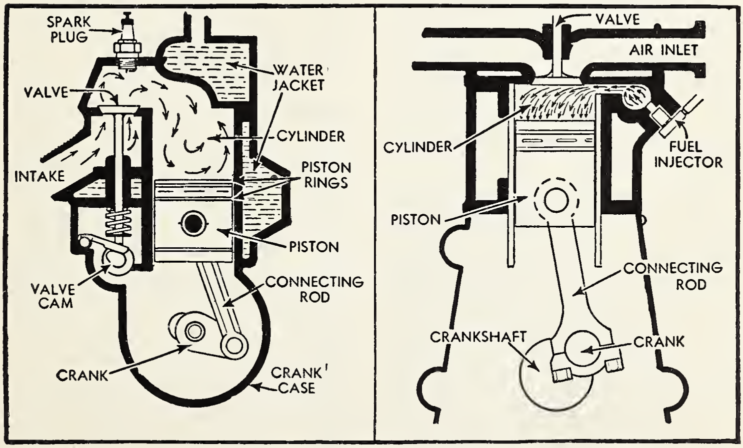
6. How do the fuel-burning engines work?

The steam engine and steam turbine are sometimes called external combustion engines because the fuels are not burned in the engines, as is true in internal combustion engines.

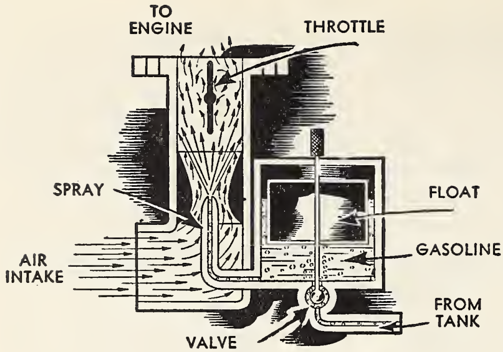
There are three types of internal combustion engines: the gasoline engine and the Diesel engine and jet engines. All of these engines burn their fuel inside the engine itself.

Internal combustion engines start instantly, without a period of waiting to generate steam. They are generally lighter and more portable than the steam engine and use a more compact type of fuel. These engines are somewhat more efficient than the ordinary steam engine but less efficient than turbines.

What are the uses of internal combustion engines? There are about 40 million automobiles in the United States equipped with gasoline engines. The farm tractor, particularly the smaller tractor, is built around a gasoline engine as a power unit. The larger



What parts of a gasoline and Diesel engine are similar? What parts does each have which are not found on the other?



General Motors Corporation

The carburetor mixes air and gasoline in correct proportions and starts the vaporizing of the gasoline.

tractors are built around Diesel engines.

The small gasoline engine is the power unit for sawing wood, pumping water, generating electricity, and running washing machines. The outboard motor is a gasoline engine.

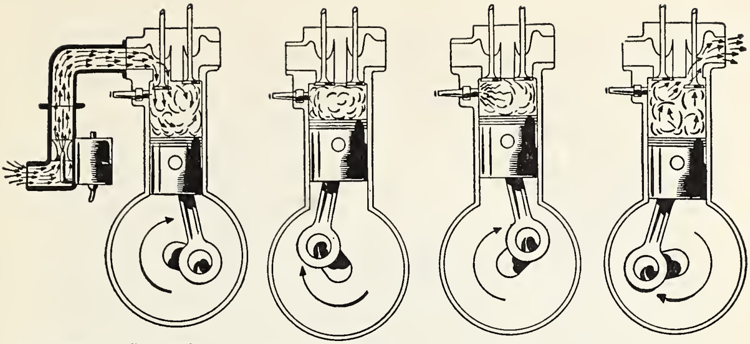
Internal combustion engines are a serious source of danger from carbon monoxide poisoning and must never be operated in a closed room under any conditions, unless the exhaust fumes are carried by an absolutely gas-tight pipe to the out-of-doors. Even then, fatal amounts of carbon monoxide may leak past the piston of the engine into the room.

How does the gasoline engine work? If liquid gasoline is run into the cylinders, the engine does not start. When this happens, the engine is flooded. The fuel must be changed to a fine spray or vapor and mixed with the right amount of air. By volume, from 40 to 60 parts of air to one part of gasoline are used.

The device which mixes the gasoline with air is the carburetor. It consists of a cup into which gasoline is forced by a pump or by gravity from the tank. The valve at the outlet of the cup is called a needle valve on account of the fact that the small opening is partly closed by a needle-like rod. The gasoline is sprayed from the needle valve into a pipe through which air flows to the engine. The gasoline is partially evaporated by the air and by the heat of the engine. The valve of the carburetor is controlled by a float and by a screw type of control.

The gasoline is ignited in the cylinders by an electric spark. The current from the generator or storage battery is stepped up by an induction coil to about 14,000 volts. This current jumps across the gap in a spark plug and causes a spark. The time at which the spark is produced is controlled by a timer operated by the action of the engine.

Practically every gasoline engine in use today is the four-cycle type. That is, there are four strokes of the piston, of which only one produces any power.



General Motors Corporation

The four strokes of the gasoline engine are shown in order. Note the position of the valves, the direction of piston movement, and the action of gases in each stroke.

The flywheel makes two complete revolutions while the piston is going through the four cycles.

The *intake stroke* pumps fuel from the carburetor into the cylinder. There are two valves on each cylinder. One admits fuel and air; the other lets out, or exhausts, burned gases. The intake valve is opened by a rod operated by the cam. (See page 341.) The intake stroke produces a partial vacuum in the carburetor, and air pressure causes the flow of fuel. The piston moves downward on the intake stroke, and fuel is admitted to the top of the cylinder.

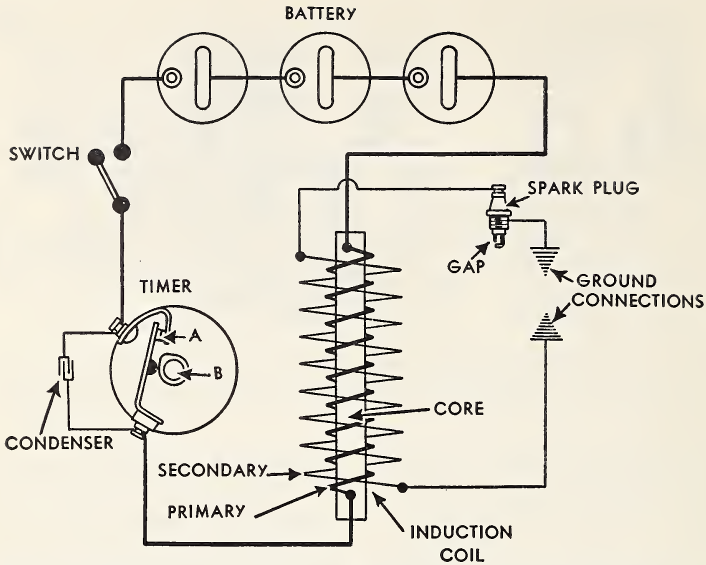
The upward or *compression stroke* of the piston compresses the mixture of gasoline and air. The temperature rises to 400 or 500 degrees Fahrenheit. Both valves are closed. The total pressure may be more than 100 pounds per square inch.

At the beginning of the *power stroke,* the spark is sent through the mixture of gasoline and air just before or at the instant that the piston is carried by the energy from the flywheel past the end of the compression stroke. The fuel burns so rapidly that an explosion results, and the piston is forced downward violently. The power is carried through a lever called a connecting rod to the crankshaft. The pressure within the cylinder may be 700 pounds per square inch.

The piston is moved up on its fourth or *exhaust stroke* by the energy from the flywheel and other pistons. The exhaust valve opens, and the piston, acting as a force pump, blows the burned gases from the cylinder through the exhaust pipe.

In the four-cylinder engine power is applied once each half revolution of the flywheel. The use of a larger number of cylinders increases the smoothness of the operation of the engine.

The engine must be started by some force outside itself, either a



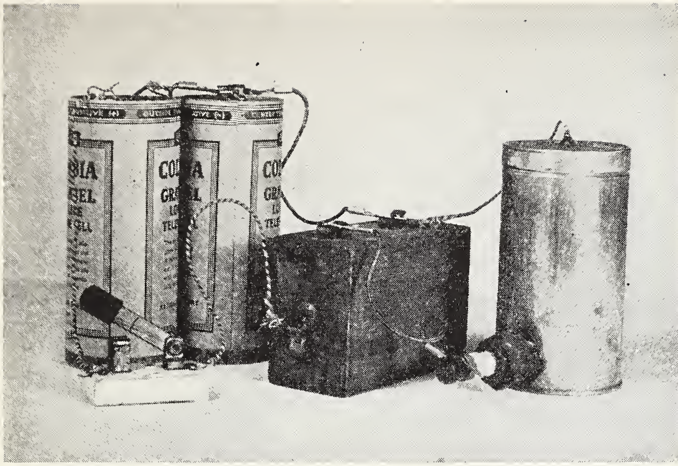
When the switch is closed, the current in the primary coil magnetizes the core and builds up a charge in the condenser. When the cam (**B**) opens the contact points (**A**), the powerful current is induced in the secondary circuit, causing a spark to jump the gap. The cam is turned by a gear on the crankshaft.

hand crank or an electric motor starter. The cranking pumps fuel into the cylinder, compresses it, and causes the spark to ignite the charge. The engine is lubricated by heavy lubricating oil and cooled by circulation of air or water around the cylinders.

How does the Diesel engine work? One kind of Diesel engine is a four-cycle internal combustion engine, it differs from the gasoline engine in several important respects. First, it burns fuel oil instead of gasoline, which makes it more economical. Second, it has no spark plugs or carburetor. Third, it does have a fuel injection pump.

On the intake stroke, the piston moves down, and a valve admits only air. On the upward stroke, the air is compressed to about 500 pounds per square inch, which raises the temperature of the air to about 1000 degrees. At the instant the compression is greatest, the injection pump shoots a drop of oil—ranging from the size of a grain of wheat to the size of a large bean—into the cylinder. This process takes about 1/4000 of a second. The oil immediately vaporizes and burns. The power and exhaust strokes are similar to those of the gasoline engine.

Diesels that are too small are not practical or economical to operate. Heavy tractors are al-



This setup illustrates the principle of the gasoline engine. The parts shown are a spark plug, can, induction coil, battery, and switch.

most always Diesel operated. So are some trucks and busses. There are many small power plants which employ Diesel engines to produce electricity or pump water. Some trains derive their power from Diesel engines.

DEMONSTRATION:
HOW DOES THE GASOLINE ENGINE WORK?

What to use: Induction coil, battery, spark plug, tin can with lid, gasoline or ether.

What to do: Cut a hole in the side of the can, and screw the spark plug into the hole. Attach the wires, as shown in the illustration, one to the plug and one to the cover of the can. Do not attach the wires from the coil to the battery until directed.

Put two drops of ether or gasoline into the can, and close the cover. Give the liquid time to evaporate. Evaporation can be speeded by warming with hot water. (*Close and remove the fuel container.*) Stand back, and connect the battery. If no explosion results, use less fuel or warm the can more thoroughly. (*This demonstration should be done only in a well-ventilated room.*)

What was observed: Describe the results of the experiment.

What was learned: What principles are used to cause an explosion of gasoline in a cylinder?

Exercise

Complete these sentences:

The gasoline and —1— are mixed in the —2—. The mixture is admitted to the —3—, where it burns. The gasoline engine is called an —4— type. The fuel passes through the intake valve on the —5— stroke. On the —6— stroke the piston moves up, and both valves are closed. The spark jumps the gap in the —7— and ignites the mixture. The exhaust

valve is open, and the piston moves up on the —8— stroke. The Diesel has no —9— or —10— as the gasoline engine has but does have an —11—. The fuel oil is ignited by —12—.

7. How do turbines and jet engines work?

It may seem strange that the simplest engines were not developed until more complex engines were in general use. The first engine ever made was a jet engine. In ancient Greece a man named Hero developed a small steam engine which worked. It was so inefficient and developed so little power, that about two thousand years passed before the principle of his toy was applied to practical production of power.

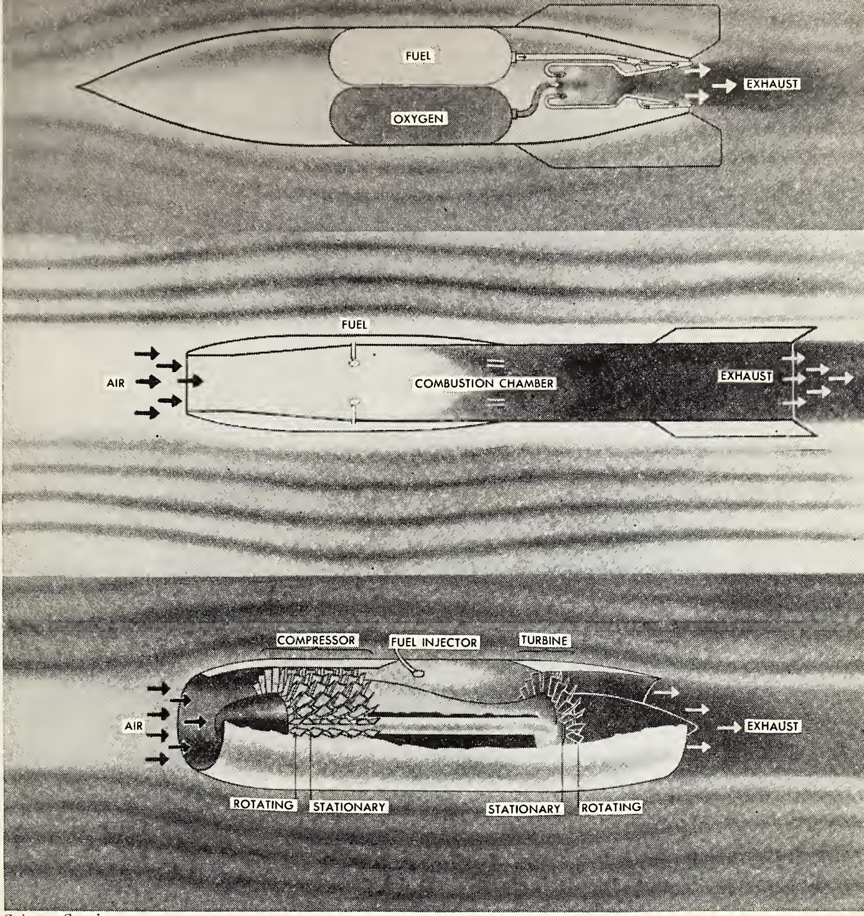
Water wheels and windmills have been in common use for many years, but the development of the turbine, which applies the same principle, is recent.

What is a water turbine? A water turbine differs from a water wheel in two important ways. It is enclosed in a casing and equipped with stationary blades, so that the force of the water is directed against the revolving blades of the turbine with little loss. The moving blades, which are also called vanes or buckets, are set at an angle so that the water strikes them and slides off. Water is led into the turbine through a pipe in such a way that its pressure is applied effectively.

The turbine is usually used to generate electricity. The turbine wheel is horizontal, and its shaft is vertical. The turbine wheel is placed at the lowest point which permits water to flow out into the stream. The shaft may extend upward many feet to the generator or dynamo. By using the turbine to drive the dynamo directly, there is no need of gears or belts and no loss of power.

Turbines and jets apply the principle of reaction. If you stand on a small boat and jump to the shore, the boat will go backward with the same force that you have in going forward. Your force in such a situation is called action, while the backward force of the boat is called reaction. You may have tried jumping from a boat, and have been surprised to discover that you did not travel nearly as far as you expected. Many inexperienced people have fallen in the water instead of landing on the ground when first trying this. Part of the force of the jump was used up in moving the boat. In the turbine the water is turned aside from its direct path by the slanting blades, and the blades are pushed aside, in somewhat the same way as you give force to the boat by jumping from it.

How do steam turbines work? The principle of the steam turbine is the same as that of the water turbine. Larger steam turbines have several sets of blades arranged in a cone-shaped casing. Between each set of revolving blades there is a row of stationary

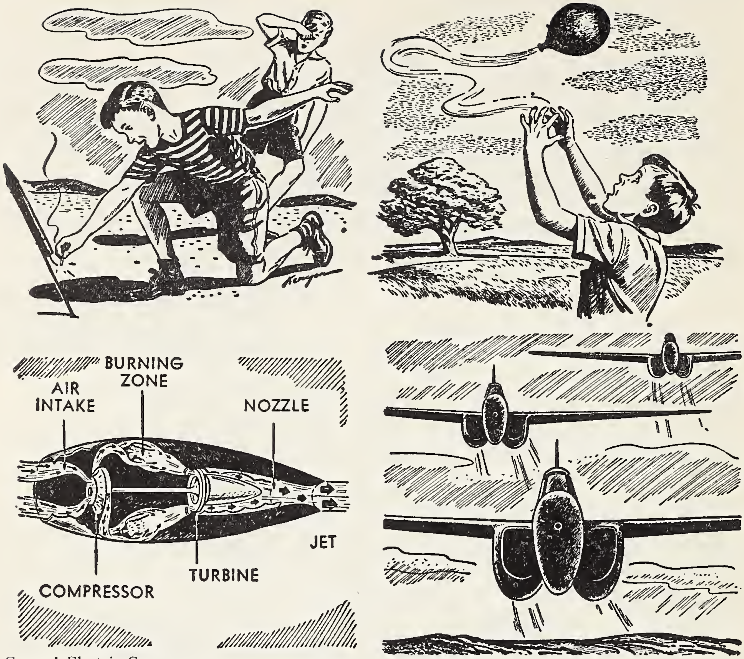


Science Service

The rocket (*top*) carries its own fuel and oxygen supply, and does not depend upon the atmosphere. The ram jet (*center*) scoops air into its open end, and is suited only to super speeds. The turbojet engine (*bottom*) is most practical at ordinary speeds, for it compresses air and feeds it into the combustion chamber. It may also be used to turn a propeller.

blades called nozzles. As the steam slides off the revolving blades, it strikes the nozzles and is directed through the casing. Steam enters the small end of the casing and expands as it passes through the turbine.

Turbines operate efficiently only when the steam is under high pressure and when the bucket blades turn very fast. If the steam is at a pressure of 1200 pounds per square inch, its temperature is about 900 degrees F.,



General Electric Company

The familiar principle of reaction is observed when we play with rockets and balloons. How is it applied in the jet engine?

which is hot enough to make the steel blades of the smallest wheels glow with a dull red light. The steam entering at this pressure passes through the turbine in about 1/30 of a second, and loses heat so rapidly that it leaves at the large end as water at 70 degrees. The pressure in the large end is so low that this space is actually a partial vacuum.

When they are turning at a rate of 1800 to 3600 revolutions per minute, the speed of the revolving buckets may reach hundreds of miles an hour, and the centrifugal force at the blade tips is many tons. Each blade is curved just right to obtain the greatest force from the steam, and is streamlined to offer as little resistance as possible to forward motion.

The development of the turbine was possible only when alloys were available which would withstand high temperatures and great forces at the same time. If a blade breaks and flies from its shaft, it has a velocity several times greater than that of an ordinary rifle bullet. Another problem which required solution was getting rid of vibration, for even

a small vibration would shake the machine to pieces in very little time.

How do jet engines and gas turbines work? The simplest jet engine has no moving parts at all. It merely burns fuel which shoots backward from the jet so fast that the engine is pushed forward. Such a simple engine actually will not work, for as soon as the air in the combustion chamber [burning area] is used up, the fuel stops burning. It is necessary to put a fan, or air compressor, at the front of the engine to supply air for burning the fuel.

A jet engine looks somewhat like a stovepipe tapered more at the back end than at the front. It usually has a shaft down its center. On this shaft at the front end is a compressor fan. Next is a curved hollow space where fuel is admitted from a series of nozzles into the combustion chamber. It burns in the compressed air and shoots with great force toward the back of the engine. Here it encounters the blades of a small turbine wheel on the back end of the shaft which turns the compressor. In a jet engine only a small amount of the energy of the burning gas is used to turn the turbine. Most of the gas, still under great pressure, enters the nozzle. The nozzle is cone-shaped. As the gases expand and shoot from the nozzle they give the engine a powerful forward thrust.

It is not necessary for the gases of a jet engine to push against the air. Their action is exactly equal to the reaction of the engine.

A gasoline turbine is similar in some ways to a jet engine. Fuel is burned in compressed air in a combustion chamber, and exerts force as it expands. The gasoline turbine has many rows of blades, perhaps a dozen or more, through which the expanding gases must pass. The gases have little energy left to produce a thrust when they finally escape from the engine.

Gasoline turbines present the same problems as do steam turbines but in a greater degree. Metals must withstand temperatures of 1500 to 2000 degrees, and speeds of many thousand revolutions per minute. Neither jet engines nor fuel-burning turbines are efficient at low speeds.

In order to reduce the great speed of turbines for effective use, a large gear wheel is turned by a small gear wheel attached to the turbine shaft directly.

Exercise

Complete these sentences:

For every action there is an equal and opposite —1—. The water turbine usually turns a —2— which extends to a —3— of electricity. Steam enters the small end of the casing and —4— as it passes through the wheels. The steam is directed against the buckets by —5—. The force of a jet engine comes entirely from —6— of the nozzle against the action of the gases. —7— must be provided to burn fuel. In a fuel-burning —8— expanding gases turn revolving blades.

8. What are some machines used in agriculture?

Most present-day farming is done with machinery operated by electric motors, or gasoline or Diesel engines. Before we can understand properly the need of using power machines, we should understand better the meaning of power. Although *power* has a general meaning, its scientific use has exact meaning.

What is power? Power is work done in a definite amount of time. When we measure work, we multiply the distance in feet through which the force acts times the force in pounds. The result is the number of foot-pounds of work done by the machine. To measure power, we consider the amount of time taken to do the work. That is, power equals work divided by time, or:

$$\text{power} = \frac{\text{force} \times \text{distance}}{\text{time}}$$

The unit for measuring power is the horsepower. Although there are many horses found on farms today which are strong enough to pull with enough energy to produce one horsepower, the average horse cannot produce work at this rate. A horsepower was defined by its inventor, James Watt, as work done at the rate of 33,000 foot-pounds per minute. Expressed as a mathematical relationship, it is:

$$\text{horsepower} = \frac{\text{number of feet} \times \text{number of pounds}}{33{,}000 \times \text{number of minutes}}$$

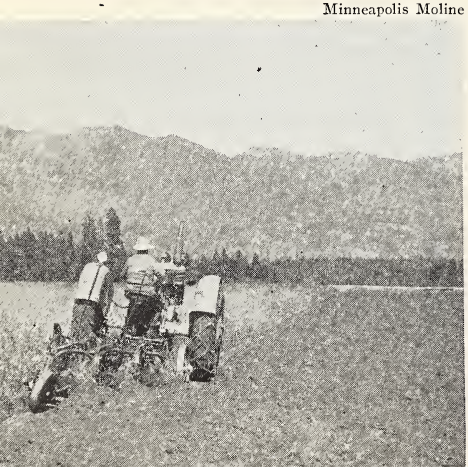
In terms of electrical energy, one horsepower is equal to 746 watts.

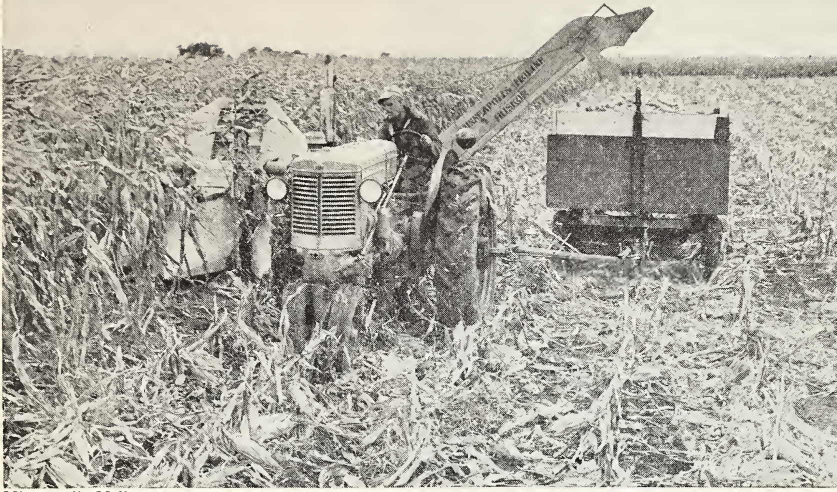
The production of work in definite amounts of time is essential in agriculture, for seasons do not wait for men. Although a farmer might move his entire crop of wheat by hand if he had a long enough time, practically it is necessary to use machines to harvest crops before they spoil. To apply power effectively, motor driven machines are used on the farm. Cultivators, harvesters, sprayers, milking machines, and many other machines make farm work easier.

How do soil cultivators work? Most of the machines used in cul-

The plow is still one of the most important machines on the farm. Note that the three plows are inclined planes.

Minneapolis Moline





Minneapolis Moline

The corn picker harvests the ears of corn, and it leaves the stalks in the field.

tivating the soil are inclined planes. The common plow has a cutting blade, called the share, and a curved incline, called the moldboard, which lifts the soil and turns it over at the same time. A tractor or horses pull by means of a bar, which may be set at various angles to cause the plow to dig deeply into the soil or to plow a shallow furrow. The furrow is the trench left by turning the soil.

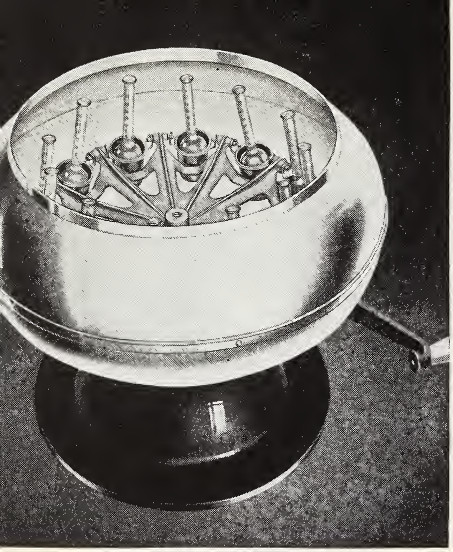
The disk cultivator is made up of many disks of steel sharpened on the edges. The disks are set at an angle to their direction of movement, which makes them inclined planes. The disk cultivator will cut as deeply as a plow does, but does not turn the soil as completely. These cultivators are used to loosen soil for planting and to kill weeds in soil in which no crop is growing.

The harrow is made up of many spikes or spring teeth, set into a steel frame. Each tooth acts as an inclined plane to cut through the soil which has been loosened by plowing. The harrow breaks up the large pieces of soil into finer particles, needed for successful seeding and holding of moisture.

The seed drill consists of a set of disks or plows which cut trenches into the soil. Behind each disk is a tube through which grain flows from a box. As the seeds fall into the trench, they are covered with soil by a dragging chain or a dragging bar.

The ordinary garden cultivator is either a small plow or a small harrow, pulled by a tractor or pushed by hand. The blades of cultivators are spaced to operate between rows of growing plants.

All soil cultivators encounter large resistances on account of



Cherry Burrell Corporation

This milk tester is turned by hand. The milk is placed in the slender bottles which are held in the metal tubes. The machine whirls the bottles to separate cream and milk by centrifugal force.

friction. To overcome this resistance, the amount of power required is fairly large.

How do harvesters work? There are many crops to be harvested, each of which requires a different harvester. Grain is harvested by a machine—the combine—which cuts the stalks, elevates the heads into a threshing machine which separates the grain from the chaff, and runs the grain through a chute into a wagon or sack. The threshing is done by running the heads between revolving cylinders full of spikes. The grain falls through sieves, and the chaff is blown away by currents of air. In other types of harvesters, these operations of cutting and threshing are separated, each machine doing part of the work. Power is supplied by horses, tractors, or steam engines.

The potato harvester is essentially a plow to which bars are attached. As the potatoes are plowed up, the soil sifts between the bars, and the potatoes roll along the bars to the ground.

Hay is cut with a mowing machine which drags a sawlike blade along the ground. While on many farms hay is harvested by hand and horsepower, the most modern method is to use a machine which collects and bales the cut and dried hay in one operation. The bales are made by pressing the hay in a boxlike cylinder with a piston, and fastening them with wire or cord binders. Bales are easier to handle and require much less storage space than does loose hay.

Most of the work of harvesting corn is done by machines. Cotton is still picked by hand, although a successful cotton picker is taking over much of this tedious work.

How do sprayers work? In gardening and fruit growing, the many insect pests can be kept under control only by use of poisonous sprays. These sprays may be applied to small areas by use of a hand-operated, atomizer-type sprayer. For spraying large orchards, the chemicals are mixed and hauled in a tank on a truck or wagon. A force pump, operated by a gasoline engine, pumps the spray from the tank through

a pipe and hose arrangement. A fine nozzle breaks the stream of liquid into a mist so fine that it looks like fog. The pressure required to produce such a spray may be four or five hundred pounds per square inch.

How do the milk separator and tester work? On dairy farms there are many interesting machines. Of these, the milk separator is one of the most important. This machine consists of a tank and whirling bowl containing many cone-shaped metal blades. These blades are whirled rapidly by a crank and gear arrangement. The milk flows from the tank into the bowl. Since cream is lighter in weight than milk, the heavier milk is whirled by centrifugal force to the outer part of the cones in the bowl, and the lighter cream goes to the inner part. The milk and cream flow from the separator through separate spouts. Large separators are operated by motors. Small ones are turned by hand.

The milk tester is a different type of separator. Milk is placed in slender-necked bottles. Chemicals are added which cause the fat in the milk to be separated from the other materials. The bottles are placed in metal tubes whirled by the gears and crank of the machine. The centrifugal force causes the lighter fat to rise to the top of the whirling bottles. Water is added to the bottles to cause the fat to rise in the neck. The amount of butterfat in the sample may be measured directly by finding the height of the column of fat in the neck of the bottle. The rotating parts of the milk tester are enclosed to avoid the serious danger that would result if a whirling bottle should break loose.

General Electric Company

The milking machine is one of the many using a partial vacuum produced by an air pump to do work. The hose by the cow's head connects to a pipeline to the pump.

How does the milking machine work? Many large dairies have milking machines. These machines consist essentially of motor-driven air pumps, which reduce the air pressure in a set of tubes. The tubes are placed over the cow's teats, and the machine alternately reduces the air pressure and permits it to become normal. The action of the air pressure causes milk to flow. The milk is collected in metal containers.

DEMONSTRATION: WHAT IS THE PRINCIPLE OF THE MILK TESTER?

What to use: Rotator and accessories, muddy water.

What to do: Set up the rotator and and the centrifuge, with muddy water in the tubes. Operate the machine, and

observe why the machine increases the speed of rotation.

What was observed: Does the machine gain speed or force? What effect has centrifugal force upon the position of the bottle holders?

What was learned: What is the principle of the milk tester?

Exercise

Complete these sentences:

A tractor pulls with a force of 1500 pounds upon a set of plows at the rate of 440 feet a minute. The horsepower is —1—. Another tractor pulls with a force of 660 pounds while moving at the rate of 12 miles per hour. Its horsepower is —2—. Most cultivators are —3— when classified as simple machines. The force which causes spray to flow from the tank comes from a —4—. The milk separator and the tester depend upon —5— force for their operation. The —6— liquid flows to the outside when whirled. The milking machine is operated by reduced —7—. Power is the production of work in definite units of —8—. The unit of measuring work is the —9—.

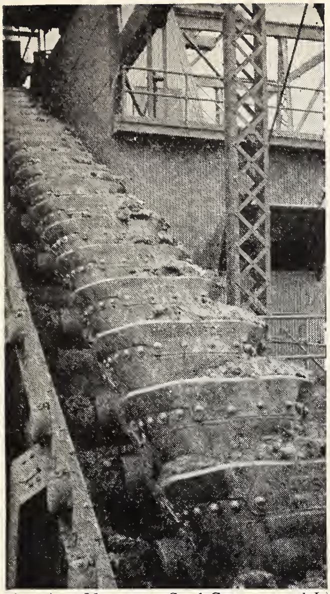
9. What are some machines used in industry?

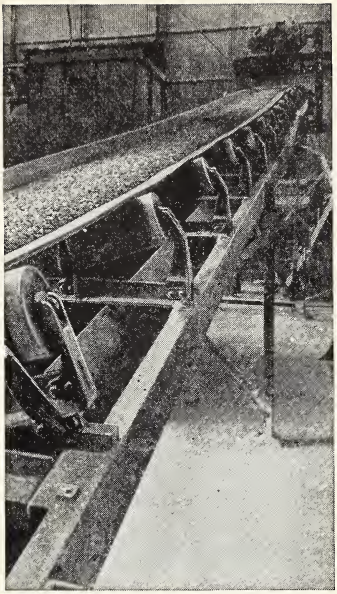
We cannot hope, perhaps, to understand many of the machines used in modern industry. There are many industries, such as textiles and shoes, oil, metalworking, printing, flour milling, lumber manufacturing, and food processing, which use highly specialized machines. Each of these machines requires hours of study for understanding the principles upon which they operate. But there are many machines so widely used in industry that it is profitable for most people to know something about them.

What are conveyers? A conveyer is a machine used for carrying materials from one place to another. Most conveyers consist of belts or chains which pass over pulleys driven by steam or electric motors. Some materials, such as coal, ore, sand, and wood chips used in paper-making, may be carried directly on the belt. Other materials require special equipment to hold them on the belt. Wet or finely divided materials, such as mud or flour, are frequently carried in metal buckets on the chain or belt.

Another type of conveyer consists of wooden or metal rollers. If an incline is sufficiently steep, boxes, packages, and large articles move down these roller conveyers because of the force of gravity. If the conveyer is level or inclined upward, the rollers are driven by belts or gears to move the articles along against the force of gravity. Lumber, packages, and other large objects are transferred from one place to another in this manner.

A third type of conveyer consists of an overhead track, like a small railroad, on which cars are driven by electric or gasoline motors. Below the cars are chains suspended from pulleys. These pulley systems lift heavy loads from the floor, and the cars carry





American Manganese Steel Company and Link-Belt Company

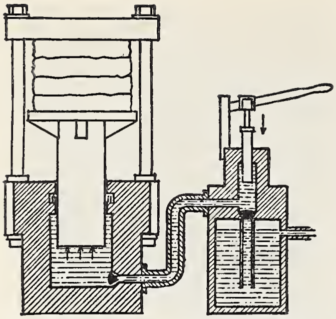
These two conveyers are of the belt type. The buckets are used on a dredge system, the belt to handle ore in a smelter. Note the use of rollers to reduce friction and to keep the belt in line.

them to new positions. This type of conveyer is used in factories for transporting heavy machines, such as locomotives and trucks, and in moving heavy ladles of melted steel. A single track and wheel is used in packing plants to move the carcasses of beef and pork.

The work done by a conveyer results from overcoming the resistance of friction or the resistance of gravity.

How do cranes and power shovels work? A crane consists of a long, third-class lever at the end of which is suspended a pulley system. The crane is used to lift heavy loads and move them. In unloading coal from a barge, a crane may be used. The long arm of the crane swings over the barge; the bucket drops down and scoops up its load of coal; the coal is lifted by the block and tackle; the crane arm swings over a railroad car; and the coal is dropped into the car. The steel cable which lifts the coal is wound and unwound on a metal cylinder called a drum. This drum is an axle of a wheel and axle.

Cranes are used extensively in loading and unloading ships. They are useful in laying steel rails and pipes. They are employed in lumbering to load



The hydraulic press consists of a force pump to exert pressure on a fluid and of a piston upon which the fluid exerts pressure. Study the diagram to locate the parts.

logs on trains. Electromagnets attached to the cables of cranes are used in moving iron bars and scrap metal.

The power shovel is exactly the same in principle as a crane. The shovel is a scoop, on the front edge of which are sharp teeth, which are inclined planes. These teeth loosen soil and rock to make it possible to scoop them into a shovel.

How does the hydraulic press work? The hydraulic press consists of two parts. The first part is an ordinary force pump, which is used to compress a liquid. The second part is a piston and cylinder. The liquid from the force pump is forced into the cylinder and exerts pressure upon the piston. The amount of force exerted by the press equals the area of the piston multiplied by the pressure. That is, a piston with an area of 300 square inches under a pressure of 200 pounds per square inch can exert a total force of 60,000 pounds, or 30 tons.

The pressure on the piston of the force pump is the same as the pressure upon the press piston, because enclosed liquids carry pressure equally in all directions. If the area of the pump piston is 10 square inches and the pump exerts a pressure of 200 pounds per square inch, the total force required is only 2000 pounds, or one ton. The hydraulic press mentioned above would give a mechanical advantage of 30. The easiest way to find the mechanical advantage is to divide the area of the press piston by the area of the pump piston. 300 divided by 10 equals 30.

The most familiar hydraulic press is that used in the barber's chair. The barber operates a pump by pressing on a pedal with his foot. The pump produces pressure on oil which flows into the cylinder and lifts the chair. The common automobile grease rack which lifts the automobile high above the ground usually obtains its force from a hydraulic press.

The hydraulic press is used in industry to shape metal. A piece of sheet metal is placed over a pattern called a *die*. The piston forces the metal into the die and shapes it. The cover and tub of your washing machine and the metal top, headlamps, and wheels of your automobile were probably pressed into shape by a hydraulic press. A hydraulic press, producing a total force of 5000 tons, is used in shaping the metal parts of the huge airplanes used

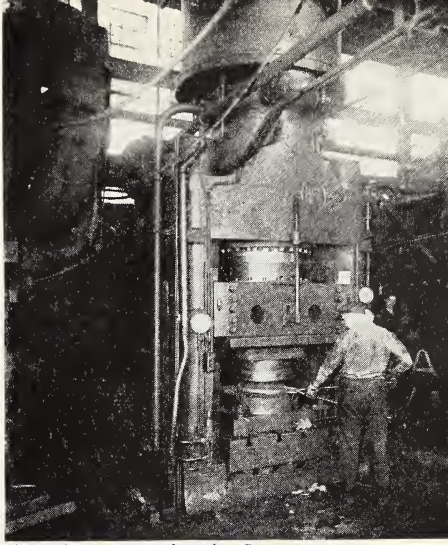
in long distance airplane service. The parts are pressed out separately and welded together to form the completed plane.

Cotton is baled by a small hydraulic press. Oil is pressed from the seeds of flax, peanuts, and cotton by hydraulic presses. These machines mold plastic materials into vanity cases, doorknobs, light sockets, and umbrella handles. They press salt into blocks, and are used in making dry ice.

What is a lathe? A lathe is one of the most essential of all industrial machines. It is really a wheel and axle. The axle is a piece of wood or metal which is attached by clamping devices to the wheels, one at each end, to hold it steady. When the wheels are rotated by power from a motor, the piece of wood or metal is turned.

To use the lathe, a cutting tool is held against the piece of turning wood. The rough stick soon becomes rounded. By moving the cutting tool to cut deeper or less deeply into the wood, beautifully curved designs are produced. The legs of furniture, such as chairs, tables, and pianos, are turned on lathes.

The metal lathe is even more important than the wood lathe. The operation is similar, except that the lathe is much stronger, it turns more slowly, and the cutting tools are held by the machine instead of by the operator. Without the lathe it would be impossible to produce the many accurately fitted parts used in modern engines, pumps, and presses. Pistons, fittings, and many other machine parts are cut entirely on lathes.

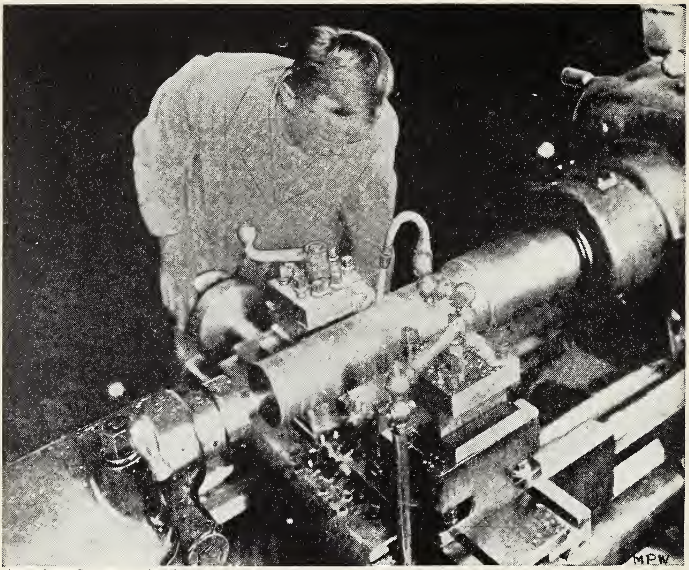


Hydraulic Press Manufacturing Company

The hydraulic press is used to shape metal. Note the huge piston above the piece of metal. Why is the metal handled with tongs?

How are grinding machines used? There are many jobs which depend upon grinding to make tools fit accurately. One of the important grinders is used to fit inside a cylinder, where it is rotated to polish and cut to size the inside of the cylinder. The modern gasoline engine would be impossible without accurately fitting pistons and cylinders.

Grinders are used to polish many metal parts. When automobile bodies are welded, the rough spots are smoothed by grinding. All sharp tools, razor blades, axes, knives, and scissors



American Tool Works Company

This lathe is used to cut metal. Note the stream of oil flowing over the metal to cool it. The operator controls the cutting tool.

are ground to produce an accurate edge.

DEMONSTRATION: HOW DOES THE HYDRAULIC PRESS WORK?

What to use: Model hydraulic press, glass jar, hot water bottle, stopper with tube connection, rubber tube, funnel, rubber band.

What to do: Operate the hydraulic press. Count the strokes of the pump needed to lift the piston. Measure the diameters of the two pistons and calculate the mechanical advantage. Observe the operation of the valves.

Put a little water in the hot water bottle to get rid of the air. Connect it to the funnel with about four feet of rubber tubing. Wrap the tubing, where it slips over the stopper connection, with a rubber band to keep it firmly in place. Squeeze water from the bag to get air out of the tubing. Lay the bottle on the table, and put four or five books on it. Raise the funnel three feet above the table, and pour water into the funnel until the bag is filled.

What was observed: How does the press work? How do the valves move on the upstroke? The downstroke?

What was learned: State the principle of the press and the method of figuring its mechanical advantage.

Exercise

Complete these sentences:

When a conveyor lifts a load, it overcomes —1—. When a load is moved on the level, a conveyer overcomes —2—. The load of a

crane is lifted by a machine called a —3—. The mechanical advantage of a hydraulic press is proportional to the —4— of the —5—. A press with a piston area of 240 square inches and a pump piston area of 12 square inches has a mechanical advantage of —6— and, with a force of 500 pounds, would press with a force of —7— pounds. Enclosed liquids exert —8— equally in all —9—. The lathe is a —10—. Grinders apply their force to overcome —11—.

10. What happens to the energy used in doing work?

As you already know, energy cannot be created or destroyed. Yet when we do work, it seems that the energy which we use has disappeared completely. What happens to it?

Do moving objects have energy? An object at rest resists being put into motion—that is, it has inertia. When energy is put into the object sufficient to start it moving, the energy is carried along in the object. The energy possessed by a moving object is called *kinetic energy*.

All objects on which work is done have kinetic energy, for work is defined as a force acting through a distance. If the object in motion encounters no resistance after it starts moving, it will continue indefinitely to move, with the same amount of energy present that it had when it started. On the earth it is completely impossible to move an object in such a way that it will encounter no resistance. The only possible situation in which an object could move in this manner would be in outer space, where there is no air, no light, and no gravitation of other bodies.

Can energy be stored? When a moving object encounters the resistance of gravity, it gradually is pulled toward the earth. If we let the object fall freely, it comes to rest on some supporting surface which it encounters—the ground, a floor, or a table top. If an object is lifted to a height and brought to rest on a support, the energy which it has may be stored up for future use. Such stored energy is called *potential energy*.

If we pump water into a high tank, the water remains in the tank, exerting pressure in proportion to the height to which it is lifted. Water at a height of 100 feet exerts a pressure of about 43 pounds per square inch at the ground, if it is carried to the ground by a pipe.

If we run the water through the pipe into a turbine, we can make the turbine do work, using the energy stored in the water.

One of our most important sources of energy is the potential energy of water stored in the atmosphere, in mountain streams, and behind high dams. The energy which is thus stored comes from the heat of the sun, which evaporates water.

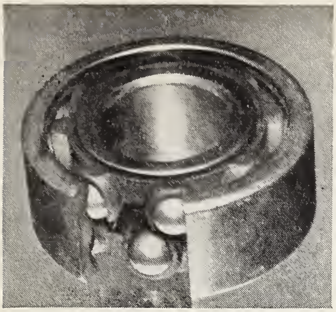
Carborundum Company

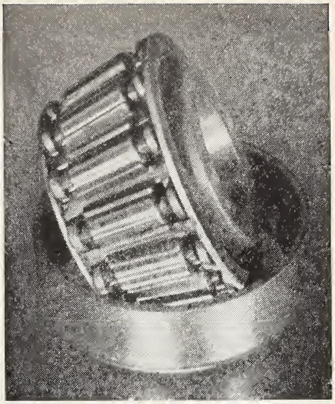
Friction produces heat. This grinding wheel throws off a shower of sparks as it cuts into metal.

Can mechanical energy be changed to heat energy? When a cold grinding machine turns against a cold piece of metal, hot sparks fly into the air. The heat comes from the energy of the moving wheel. Friction causes mechanical energy to produce heat. The heat is radiated into space and lost. If the grinding continues for some time, the wheel and metal may become hot enough that the metal glows. Then we can see light and feel infrared radiation.

The spectacular sparks given off in grinding metals make it possible for us to see the heat loss usually not noticed. All friction produces heat. When a stone falls to the ground or when a drop of rain falls to the earth, its kinetic energy is changed to heat. The net result of most work is to change energy to heat, for it is only rarely that we store as potential energy even a small fraction of the kinetic energy held in the moving object.

An interesting experiment can be done to measure roughly the amount of heat produced in doing work. A cardboard tube three feet long is closed with corks at each end. In the tube two ounces of shot are placed. Then the tube is turned over, end for end, and the shot allowed to drop the





The ball bearings (*left*) reduce friction. Part of the metal ring has been cut away to show the bearings. The tapered roller bearings (*right*) have been removed from the metal ring into which they fit.

length of the tube. With each eight turns, three foot-pounds of work are done. The shot is then poured into water. If water, shot, and tube are at room temperature at the beginning of the experiment, any increase in the temperature of the water is caused by the changing of mechanical energy into heat.

What is efficiency? In every machine there is much waste of energy. Not only is there friction, but there is loss of energy caused by moving the parts of the machine. That is, when we lift sand on a shovel, we lift not only the sand but also the shovel. All the effort used in lifting the shovel is wasted.

We can measure the useful work done, and we can measure the total work used to produce the useful work. Efficiency is defined thus:

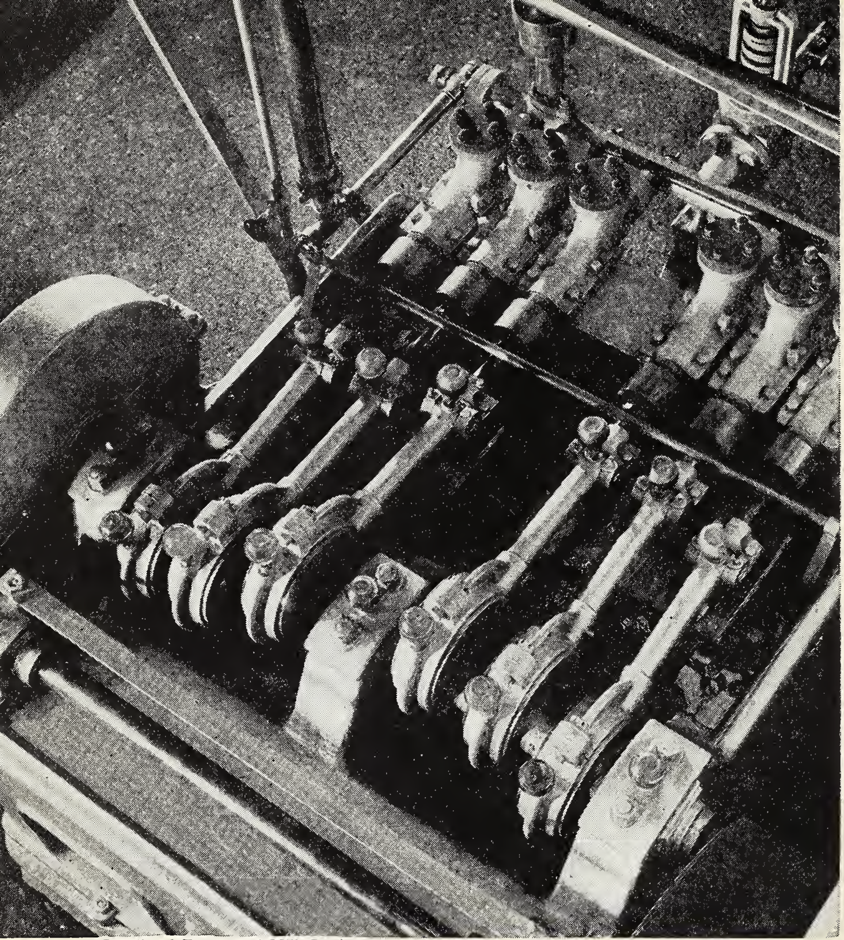
$$\textbf{efficiency} = \frac{\textbf{useful work}}{\textbf{total work}}$$

For example, suppose that 240 pounds of bricks in a box are being lifted with a block and tackle to a distance of 10 feet. The box weighs 40 pounds. Then there is friction in the pulleys and in the blocks where the ropes drag. The total amount of work done to lift the bricks is 3200 foot-pounds. The efficiency of the system is:

$$\frac{240 \times 10}{3200} = .75$$

The highest possible theoretical efficiency is 100 per cent, but no machine can possibly be that efficient.

How is efficiency increased? There are several ways in which efficiency is increased. One way is to reduce friction. Oil and smooth surfaces reduce the friction of many common machines, such as the sewing machine, the washing machine, and the gasoline engine. Use of rolling instead of sliding friction increases efficiency. The wheel makes a toy wagon more efficient than a sled drawn along a concrete walk. Ball bearings are used in roller skates



Irradiated Evaporated Milk Institute

The rotary motion of the crankshaft is changed to back-and-forth motion of the six rods which operate six force pumps.

and bicycle wheels to reduce friction. Trains, trucks, and heavy machines use roller bearings to reduce friction.

A second way of increasing efficiency is to reduce the weight of the moving parts of the machine. If a light machine will do the work as well as a heavy machine, it is cheaper to use the lighter machine. Heavy machines have greater weight and more inertia to overcome.

A third way to increase efficiency is to keep moving parts in motion. Every time a part of a machine stops, its kinetic energy is changed to heat by friction and is lost. Rotating motion is less wasteful of energy than

back-and-forth motion. This fact explains in part why turbines are more efficient than other engines.

DEMONSTRATION: HOW DO WE MEASURE EFFICIENCY?

What to use: Board, brick, spring balance, cord, ruler.

What to do: Set up the board as an inclined plane. With the spring balance, drag the brick up the board, noting the amount of force needed. Measure the length and height of the plane.

What was observed: Calculate the total amount of work done by multiplying the force used on the balance times the length of the plane. Find the useful work by multiplying the height of the plane by the weight of the brick.

What was learned: Calculate efficiency. What was it?

Exercise

Complete these sentences:

A moving object has —1— energy. An object at rest may have —2— energy because of its position. Energy that is not stored as potential energy is changed to —3— by —4—. Energy, although not —5—, is lost into space completely by the process of —6—. Efficiency equals —7— divided by —8—. Friction may be reduced by use of —9— on smooth surfaces or by use of —10— friction. Heavy machine parts are wasteful because of the resistance of —11— to lifting weights.

A review of the chapter

A machine is a device for applying force advantageously. Mechanical advantage is the number of times a machine multiplies the force put into it. Simple machines are the three classes of levers, inclined planes, the pulley, the wheel and axle, the wedge, and the screw. Work is done when force acts through a distance. Energy used in doing work is changed to heat by friction or is stored as potential energy. A moving object has kinetic energy.

Force is applied to pistons or to revolving blades. Centrifugal force is the tendency of rotating objects to move in straight lines. All complex machines are made up of simple machines and working surfaces.

Power is the production of work in definite units of time.

Word list for study

machine	crane	hydraulic press	eccentric
resistance	kinetic	potential	carburetor
inclined plane	work	force	power
turbine	fulcrum	lever	horsepower
cylinder	jet engine	vane	lathe
governor	centrifugal	piston	efficiency
crank	safety valve	flywheel	internal combustion
exhaust	Diesel	mechanical advantage	
conveyor	atomizer		

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Work is a force acting through a distance.

B. Force times distance equals resistance times distance.

C. Kinetic energy is the energy of a body in motion.

D. Potential energy is the energy possessed by an object because of its position.

E. One form of energy may be transformed into another form of energy.

F. Useful work divided by total work equals efficiency.

G. When unequal forces act upon an object the object tends to move in the direction of the greater force.

H. An object at rest remains at rest and an object in motion continues in motion in the same straight line unless acted upon by an outside force.

I. Power is the production of work in definite units of time.

J. For every action there is an equal and opposite reaction.

List of related ideas

1. The unit of measuring work is the foot-pound.
2. With one movable pulley, it is necessary to pull two feet of rope for each foot the load is lifted.
3. A brick on a wall contains energy.
4. A nail becomes hot when driven into a board.
5. Rotating objects tend to fly out in straight lines.
6. Steam engines waste 90 per cent of their energy.
7. A swinging hammer delivers a heavy blow.
8. A gun kicks when the bullet is shot forward.
9. 33,000 foot-pounds of work per minute are one horsepower.
10. Jet engines are pushed ahead as gases shoot backward.
11. A pump valve is opened and closed by the flow of water.
12. We do no work unless an object is moved.
13. Steam exerts force upon the piston of an engine.
14. Use of oil on a machine increases its efficiency.
15. The faster an object moves, the harder it hits an obstacle.
16. Water behind a dam has energy stored in it.
17. A machine with whirling blades may be more efficient than a machine with a back-and-forth motion.
18. If a string tied to a weight is jerked, it breaks.
19. Heat is used in engines to do work.
20. Farmers use tractors to get work done in time to save crops.
21. Mechanical advantage is the

number of times a machine multiplies the force put into it.

22. Automobiles skid in turning corners rapidly.
23. Distance on a lever is measured from the fulcrum.
24. When you jump from a boat, the boat moves backward.
25. A machine that increases the speed decreases the force.
26. A single fixed pulley gives a mechanical advantage of one.
27. Expanding gases in an engine provide force to do work.
28. The arms of a rotary lawn sprinkler move in a direction opposite to that of the water.
29. Energy is stored between strokes of an engine in the flywheel.
30. Molecules of steam take up about 1700 times as much space as do the same molecules of water, because they have more energy.
31. One horsepower equals 746 watts of electrical energy.
32. Running water can do work.
33. Much work is done in lifting loads against gravity.
34. A power machine can do work in less time than a man can by using his muscles.
35. Simple machines usually waste less energy than do complex machines.
36. The work done by use of an inclined plane equals the height of the plane times the weight of the load.
37. The mechanical advantage of an inclined plane equals length divided by height.
38. Wind exerts force upon the front of a windmill vane.
39. Roller bearings in train wheels reduce friction and loss of energy.
40. A bent bow has energy stored in it.

Some things to explain

1. Describe the changes which take place in iron from the ore to the form of an automobile fender. List the machines used in the work.
2. List 20 simple machines used in the home, and explain how they are used.
3. Why do we say that machines cannot save work? What do they actually save?
4. How many simple machines are there in a pencil sharpener? Name them.
5. How many horsepower are produced by a generator which produces 150,000 kilowatts?
6. What advantage does a turbine have over an ordinary steam engine?
7. Why is the large sprocket of a bicycle in front?

Some good books to read

Compton's Pictured Encyclopedia

Dunn, M. L. and Morrisett, L. N., *Machines for America*

Dunn, M. L. and Morrisett, L. N., *Power for America*

Degler, H. E., *Diesel Engines*

Huey, E. G., *What Makes the Wheels Go Round?*

Morgan, A. P., *Boys Book of Engines, Motors, and Turbines*

Reck, F. M., *Automobiles from Start to Finish*

Reck, F. M., *Power from Start to Finish*

Zim, H. S., *Rockets and Jets*

Yates, R. F., *Boy and a Motor*

CHAPTER

8

Houses for Modern Living

A house may be made in many ways, and of many materials. It can cost relatively little or it may cost millions of dollars. It can be built in any style, ranging from log cabin to very formal classical style. It may be small—a one-room shack—or it may be an apartment building providing homes for hundreds of families. It may have no equipment in it whatsoever, or it may have elaborate machinery to make work easier, to condition the air, and to control the light. All houses do provide shelter.

Every house that you can find was built by somebody to meet his needs for living. Houses differ as peoples' ways of living differ. Because most houses last a long time it is important that a house be built so that it may be used by various people before it is worn out. Extremely large and expensive houses are generally torn down, or sold at a loss and divided into apartments, long before they are worn out. Unusual houses are likely to be sold by the builder at a loss because other people do not like unusual houses.

Because houses do last so long, the average person is living in a house 20 to 30 years old. This means that the house is out of date in many respects, even if it has been kept in good condition by remodeling. Unfortunately new houses are being built which are much like these old houses, and are out of date when built. It is extremely important, in designing a house, to make it just as modern and practical as possible. It will affect the lives of the people who live in it for 30 to 100 years.

Some activities to do

1. After you have studied this chapter, make a check list from Problem 1, pages 368 to 372, and rate your house as to how nearly functional it is. There are 16 points to check. Giving 5 points for best conditions under each heading, a perfect score would be 80.

United States Plywood Corporation

One of the important advantages of building a new house is that we may choose from a large variety of building materials. This living room has walls, doors, ceiling, and built-ins made of oak plywood.

2. Visit a house under construction, and observe the various steps involved in building a house.

3. Make a collection of wood samples used in your community. Varnish one-half of each sample.

4. Make a collection of all the earth products mentioned in this chapter, and label the specimens.

5. Study the school heating plant, learning especially how the heat is carried into the rooms.

6. Learn exactly how your own heating plant works and compare it with a different type of plant.

7. Make a model thermostat. You can make a compound bar if you can rivet strips of the two metals together.

8. Make a model hot-water tank, using cans and copper tubing. It will be necessary to solder the joints.

9. Make a study of your home lighting. Are the curtains properly placed? Plan a better method of lighting your home.

10. Obtain floor plans from papers or magazines. Shade with pencil lines all halls and stairways and all spaces where doors swing. Shade in black the fireplace and sunroom. Draw in red the paths through various essential rooms, as from the kitchen to the living-room door. Select the least wasteful plan.

11. Draw an original house plan to scale.

12. Arrange with the owner of a business equipped with air-conditioning equipment to allow you to observe how the machinery operates. Where does the heat go when it leaves the room?

13. Using thermometers from advertising matter, make a wet-and-dry-bulb thermometer. Look up tables to accompany it in reference books.

Some subjects for reports

1. New uses of glass, and new kinds of glass
2. Labor-saving kitchens
3. Special plans for houses on hillsides
4. The best size for a lot for a single dwelling
5. Zoning regulations in your city
6. Houses for ranches and farms
7. New methods of heating houses
8. Fire-resistant materials for house construction
9. Ways of disposing of houses too old for use
10. Modernizing and remodeling older houses
11. Relation of color to safety and light
12. Methods of letting in light while keeping out heat
13. Prefabricated houses of different kinds
14. How plasterboard is made and used

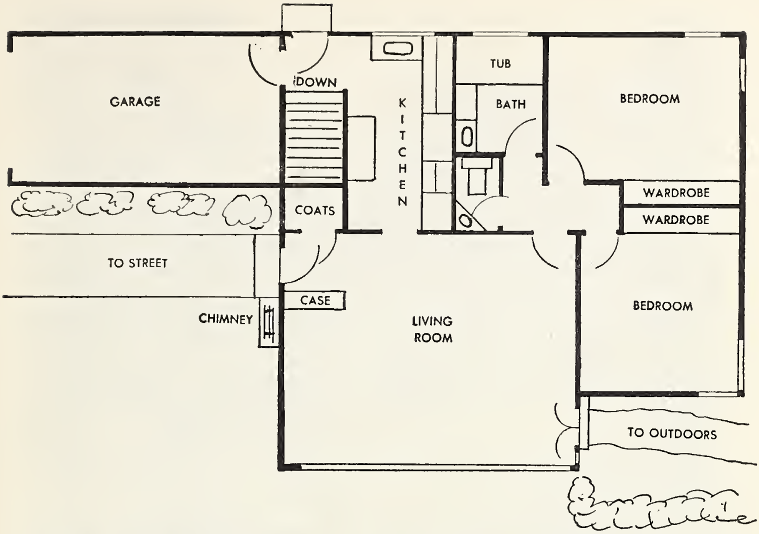
1. What is a functional house?

A house is functional when it best serves the purpose for which it is intended. A traditional house, on the other hand, follows a certain style of pattern even when greatly improved methods are available. A functional house is built around the activities and needs of people. The chief activities are centered around work and play, eating, keeping clean, and sleeping and resting. People also need places for storing their belongings. In order for us to be healthy and comfortable, the temperature and condition of the air must be controlled. People need good light for seeing, and privacy in order to enjoy independent living. A functional house is built around modern ways of living.

What are some tests of a functional house? A house may be said to be functional insofar as it meets human needs. All houses are functional to some extent. Some older houses were functional, when built, for living under conditions existing in the past.

A functional house provides privacy from outside the house, without sacrificing light and space. The living area may be placed at the back of the house or on one side with large windows facing an open space. Some windows may be made of translucent glass. Trees and shrubs are planted far enough from the house to screen it and yet let in light.

Space for outdoor living is provided away from the street. This space may be screened by walls or hedges, or left open. Living rooms may be made so that they



This house plan is compact and convenient. Note especially the location of the garage, the use of wardrobes between bedrooms, the separate toilet space, and the placement of windows.

open directly outdoors upon terraces.

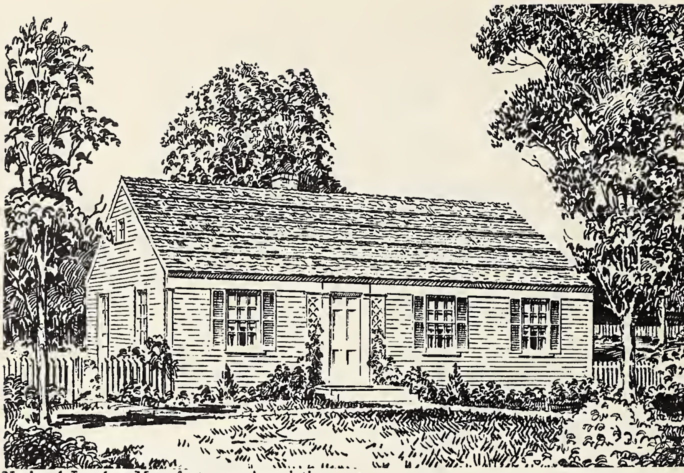
Access to the functional house is easy. The garage may be entered from the house, and it is placed near the street or roadway. The entry hall is convenient to the street and to the living and work spaces. It provides a place for outdoor clothing.

The exterior design of the house is determined by the placement of rooms and windows for convenient living. To achieve attractive design it is not necessary to place windows in exact pairs, or to put the door exactly at the center of the house. The functional house is not loaded with useless ornaments.

The house has fewer but larger rooms designed for general use. There are few special rooms such as the breakfast nook, pantry, sun porch, parlor, reception hall, and dressing rooms.

The functional house provides privacy within the house. Areas for work, for living, and for rest and sanitation are separated from each other. Halls, lockers and closets, and partitions are used to separate various activities, and to provide soundproofing. When possible, bedrooms are made large enough to provide a little private living space.

The functional house makes good use of the sun for heat and light. Large windows admit heat and light in the winter, and admit light without heat in the summer. The house is cheerful and bright.



National Lumber Manufacturers Association

Compare this floor plan with others in this chapter. This is a traditional small house plan. Note that shutters make small windows look larger.

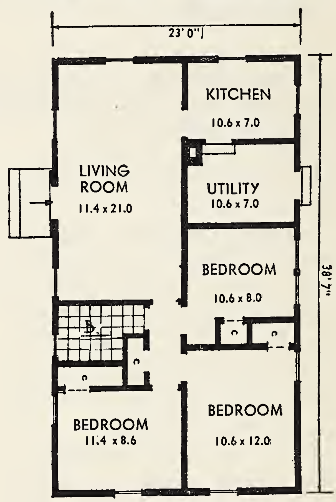
Color is used to make seeing easy, and to provide restful surroundings. Purely decorative color schemes are not used.

Plumbing is placed for convenient use, and is close together for economy. The laundry is bright and cheerful.

Conditions of heat, humidity, and air circulation are controlled easily or automatically. Comfortable living is possible at all times.

The house contains space for furniture and equipment needed for living. It is not cluttered up with misplaced windows and doors, open stairs, radiators, and fireplaces.

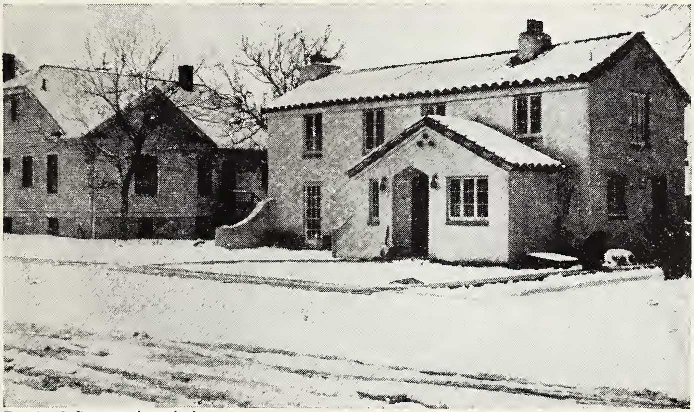
The functional house is designed for use. Its floors, walls and woodwork are durable. Built-in equipment has definite uses.



The functional house is not loaded with gadgets, useless drapes, and museum-type furniture.

The house is durable and easy to maintain. It is built of durable materials, needs little painting, does not have windows and screens to put on and remove.

The interior of the house is



Portland Cement Association

It is difficult to recognize the substantial old barn above as being part of the modern house below. The walls of the remodeled house are covered with stucco.

easy to keep clean. Washable materials are used for such things as flooring, wall covering, and needed draperies. Smoky fireplaces, dirt-catching rugs, cracks in floors, and useless curtains are not necessary in functional houses.

It is fire resistant and safe to live in. Safe equipment is used, and fire-resistant building materials are preferred. Electrical equipment is safely installed. Stairs, if there are any, are well lighted and wide enough. Light colors in work areas increase safety. Storage is provided for those things which cause falls, cuts, or other injury.

The functional house makes use of the best materials available. Stone, brick, and concrete may be used for outside walls. Composition tiles may be used

instead of polished wood and rugs for floors. Metal or mineral composition roofing may be used. Double-pane glass may be used in cold climates.

Can you have a functional house? Most of the houses we live in are old and were built before people understood the advantages of functional house planning. Living conditions have changed since old houses were built. Many new houses are built by people who lack understanding of modern living conditions. Houses cost so much that many people cannot afford some desirable features of functional houses.

Fortunately old houses can be greatly improved by remodeling. Larger windows, clean walls, new light fixtures, white ceilings, modern composition tile floors, new sinks and bathroom equipment, freshly painted woodwork, and perhaps some changes in partitions will greatly improve many old houses. Many houses are improved by removing useless ornamentation and porches. Insulation may be put into old houses and will make them more comfortable to live in. Basement windows may be enlarged and filled with glass block. Fans improve circulation of air both in summer and winter.

Your chances of living in a truly functional house are very small. A good many people like old-fashioned, inefficient houses, and they are continuing to build them because they do not know that something better is available. A house lasts a long time, and someone must live in it because of its cost. It is costly to build houses which contain all desired features. Houses which are functional today will become out of date as conditions change. The average new house is a compromise between what is desired and what people can afford. Even so, many new houses are not as good as they should be.

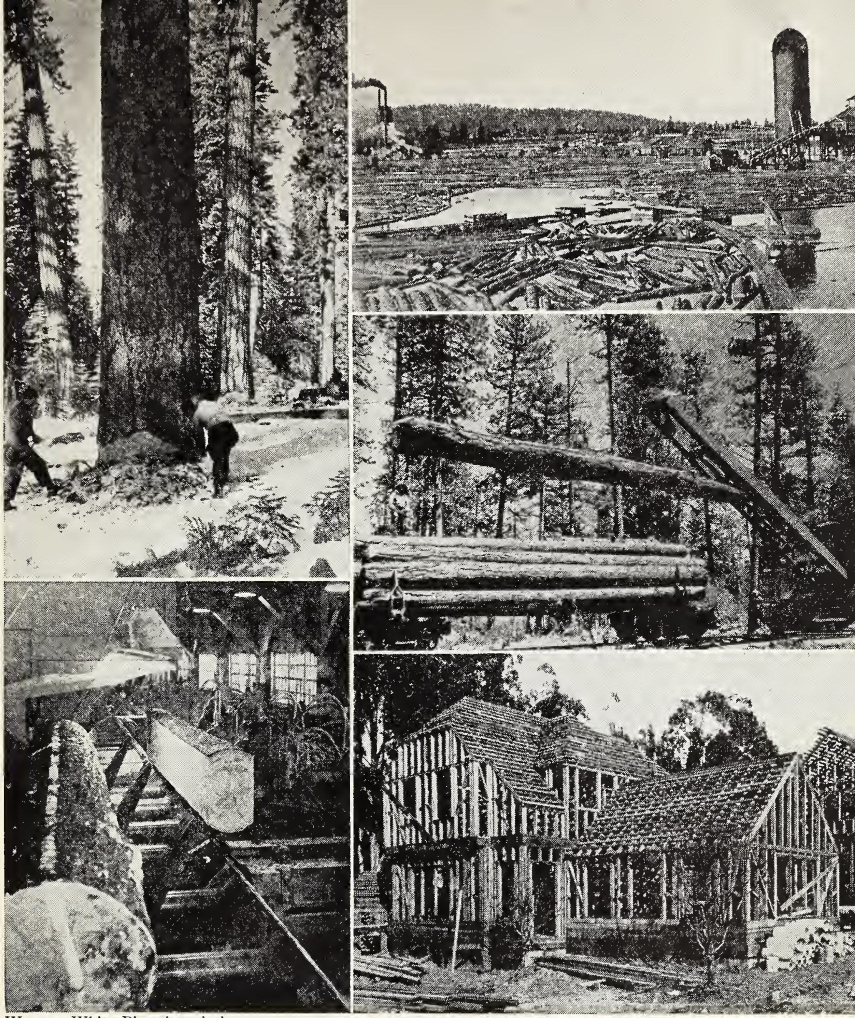
Exercise

Make a table by ruling your paper into two columns. Head the columns as follows: FUNCTIONAL, TRADITIONAL. *In the correct column write the following*: separate garage, air conditioning, large windows, light colors, sun porch, decorative shutters, basement laundry, fire-resistant materials, simple design. Read the text and find ten other items to add to each column.

2. What plant materials are used in building?

Plant materials are available to the builder today in numerous forms. Of the new materials some have outstanding merit while others may prove to be only poor substitutes for better materials.

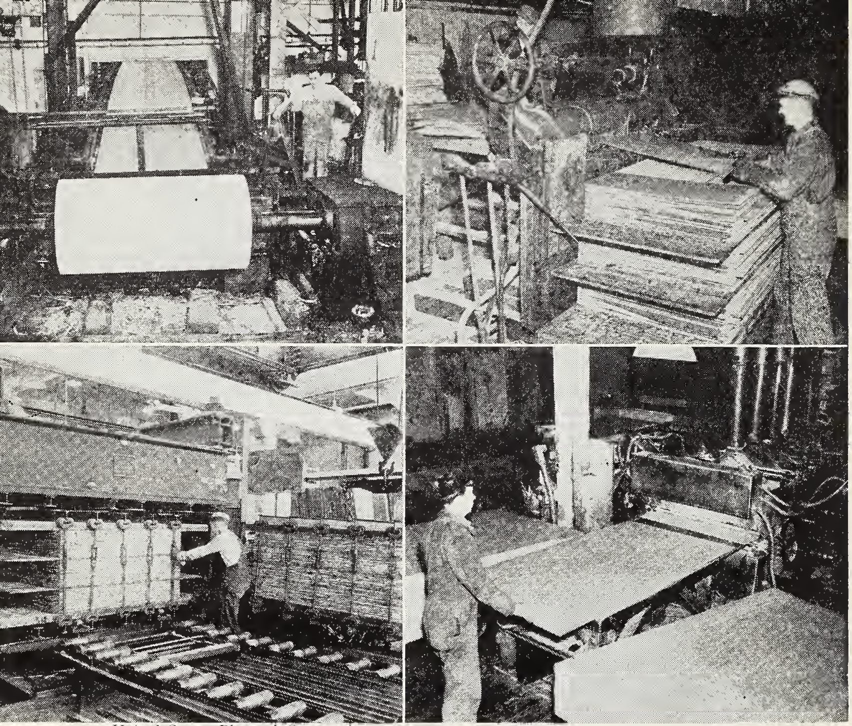
What is lumber? Lumber is the commonest material used for building inexpensive houses and is extensively used in most houses. It is fairly cheap, widely available, easily worked, and ac-



Western White Pine Association

The trees which are felled in the forest (*top left*) are cut into logs and loaded on trains (*center right*). At the sawmill (*top right*) the logs float in a pond until needed. Boards are then sawed from the log (*bottom left*) which is moved past the saw on a complex carriage and the finished lumber is used in building houses, such as the one shown at the bottom.

cepted by most people as the standard building material. It is not particularly durable. It warps and shrinks in changing weather. It leaks air through the pores and cracks. It burns readily.



United States Plywood Corporation

Reading from top, left to right, these pictures show veneer being cut from a log by a blade held against the rotating log; strips of veneer being glued and (*bottom*) pressed together in a hydraulic press; and finishing the outside surfaces of the plywood by sanding machines.

More lumber is made from pine trees than from any other kind, with Douglas fir second. These two softwoods provide three-fourths of our lumber. The commonest hardwood is oak, which accounts for 6 per cent of our lumber. Cypress, redwood, and cedar are desirable woods for resisting weather. Cedar is the most used wood for shingles. Most of the other woods are used in small amounts for trim, flooring, and furniture.

How is plywood made? To make plywood, a thin layer of wood is peeled from the log by a long knife held against the log as it is rotated in a lathe. Three or more layers of thin wood, called veneer, are glued together. The grain of one layer runs at right angles to the grain of the veneer next to it.

The glued plywood is stacked in a hydraulic press and forced together under a pressure of 200 pounds or more per square inch. After six hours the glue is set. The surface of the plywood is finished by sanding machines. The smooth plywood is easily

worked, has interesting grain, and is amazingly strong. A waterproof plywood is available, bonded with plastic instead of glue. Some plywoods have surfaces of plastic or metal.

The grain of boards and plywood depends upon cutting through the annual rings of growth in such a way that the edges of the cut rings show in patterns. If the rings are cut to show the edges, the boards are quarter-sawed. If the rings are cut at an angle of less than 45 degrees, the grain is slash grain. Most plywood shows a slash grain.

How are fiberboards and paper made? Fiberboards may be almost as hard as metal or as loose and porous as a quilt. The fibers used may be from sugar cane, flax, or wood. Some are white, some tan, and some brown.

To make fiberboard from wood, the logs are reduced to chips, which are sorted by screens and fed into tanks. Steam is admitted to the tank under pressures reaching 1000 pounds per square inch. Suddenly the tank is opened, and the fibers are loosened from each other by the expanding steam. The fibers mixed with water are run on a screen or blanket, and the water is withdrawn by vacuums and by pressure rollers. The fibers mat together. When a sufficient thickness is built up, the boards are pressed. To make a hard, polished board, a board 4×12 feet is subjected to a pressure of 1000 tons. Softer boards are subjected to less pressure.

The soft fiberboards are used for insulation and for deadening sound. Hard fiberboards are used for decoration, table tops, walls, and shelves.

Paper is made from fiber by a process similar to making fiberboard. Loose fiber is blown into spaces between walls or formed into quilts between layers of paper.

Some roofing is made from felt, which is made from cloth fibers. The felt is soaked in hot tar and pressed between hot rollers. A hard, waterproof finish is produced. Sometimes gravel is pressed into the surface of roofing, making it more fire-resistant and durable.

How are plant materials protected? Plant materials are generally soft, subject to decay, and often unsightly. They are usually painted or varnished. Paint consists of three kinds of materials—oxidizing oils, driers, and pigments. The common oxidizing oils are linseed oil and tung oil, but several synthetic oils are now used. When these oils dry they make a tough, hard finish. The driers, of which turpentine and light petroleum oils are examples, thin the paint for easy spreading and hasten its drying. Pigments are finely ground minerals, chemicals, or metals.

Varnish is made of either natural or synthetic resins dissolved in oils. Shellac is made of resins dissolved in alcohol.

Many paints consist of organic materials, such as caesin from milk, or other plastics which dis-

solve or are suspended in water. They are not washable, and some of them will mold, decay, or mildew when damp.

What plastics are used in building? Few plastics have been thoroughly tested for house construction. They may eventually be used for roofing, furniture, flooring, fabrics, windows, wall tiles, plumbing, and many other purposes. Today they are used in shower curtains and drapes, for electrical outlets and switches, insulation, paints, wall coverings, upholstery, and for bonding wood, cloth, and paper.

DEMONSTRATION: WHAT ARE THE DIFFERENT WOODS USED IN BUILDING?

What to use: Wood samples.

What to do: Examine the grain of the wood with a magnifying glass. If the samples are not too valuable, test for hardness by scratching with the grain and across the grain with a nail. Split a piece of the wood. Observe how the wood breaks. Do large splinters form? Is the wood strong or weak? Polish a piece of wood with wax on a cloth. Can you make it shine?

What was observed: Make a table to record your observations.

What was learned: What are the characteristics of each wood?

Exercise

Complete these sentences:

The most widely used wood comes from the —1— tree. The commonest hardwood is —2—. The annual rings of growth give wood its —3—. —4— is formed by gluing together thin strips of wood called —5— under pressure. —6— are made by pressing together wood, cane, or flax fibers. Plant products are good —7— of heat and electricity. —8— contain mineral pigments, while —9— contain resins dissolved in oil. —10— consists of resins dissolved in alcohol. The most important plant material used in building is —11—.

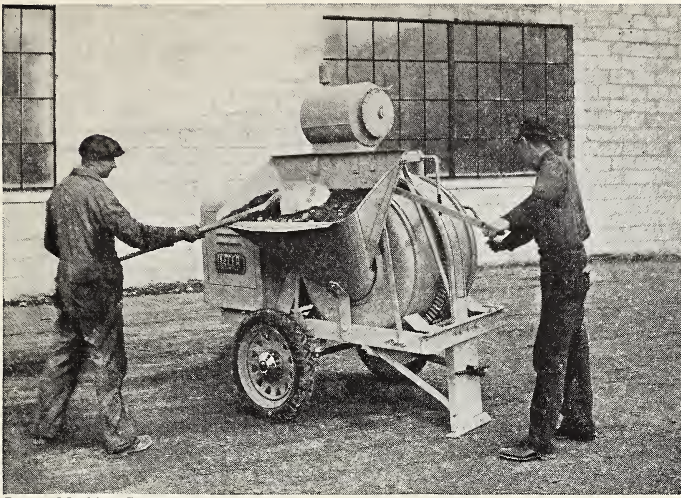
3. What minerals are used in building?

The materials obtained from minerals, the metals and the stonelike earth materials, are alike in being fireproof, durable, and generally fairly difficult to work into buildings. They are fairly poor insulators against heat, metals being the poorer. Most earth materials are electrical insulators, while metals are conductors.

How is stone used in building? A common building stone is granite. Granite is hard, coarse-grained rock which can either be given a glasslike polish or left rough. It is the most durable of the common building stones.

Sandstone and limestone are easily worked but weather and crumble fairly rapidly. Limestone often is light colored, tending toward gray and yellow; while sandstones are often darker, tending toward red and brown in color.

Marble is the most beautiful and expensive of the building



Jaeger Machine Company

In a concrete mixer cement, sand, gravel, and water are stirred into a uniform mixture.

stones. It takes a glasslike polish and occurs in a great variety of colors and patterns. Using stone for building helps conserve our forests.

Stone is removed from the earth in quarries. The quarry is usually equipped with cranes, blasting equipment, and drills and saws. The stone is cut from the bedrock and broken or cut into convenient-sized pieces. The stone then is lifted from the quarry and cut or polished as required. Many houses are made of field stones.

Stone houses are durable and may be attractive in appearance. They require insulation inside the walls for warmth.

How are cement and concrete made? Portland cement, which is used in making concrete, is made from limestone heated in kilns with the right proportion of clay. Gypsum, a mineral, is added to the mixture after the limestone has been heated in a kiln until it crumbles to a powder. The three materials are ground very fine, sifted through silk, and sealed in waterproof bags. Masonry cement is similar to Portland cement.

Concrete is an artificial stone made by mixing cement, sand, gravel, and water. A mixture suitable for use around the home consists of one part cement, two parts clean, sharp sand, and four parts gravel. Water sufficient to make a thick "mush" is used. The mixtures richer in cement are more nearly waterproof.

Concrete is poured into forms made of lumber or plywood. The

Louisville Cement Company

Mortar is used to form a bond and seal the spaces between bricks.

steel bars used for reinforcement are placed inside the form, and the wet concrete is poured in. It hardens enough in a few hours to permit removal of the forms and continues to harden for weeks. Concrete obtains its strength from the entangling of crystals of cement around sand.

Concrete is one of the most important building materials, for it is used in basement walls, for building blocks, for floors, for entire houses, for walks and steps, for posts, for septic tanks, for well covers, and for bird fountains.

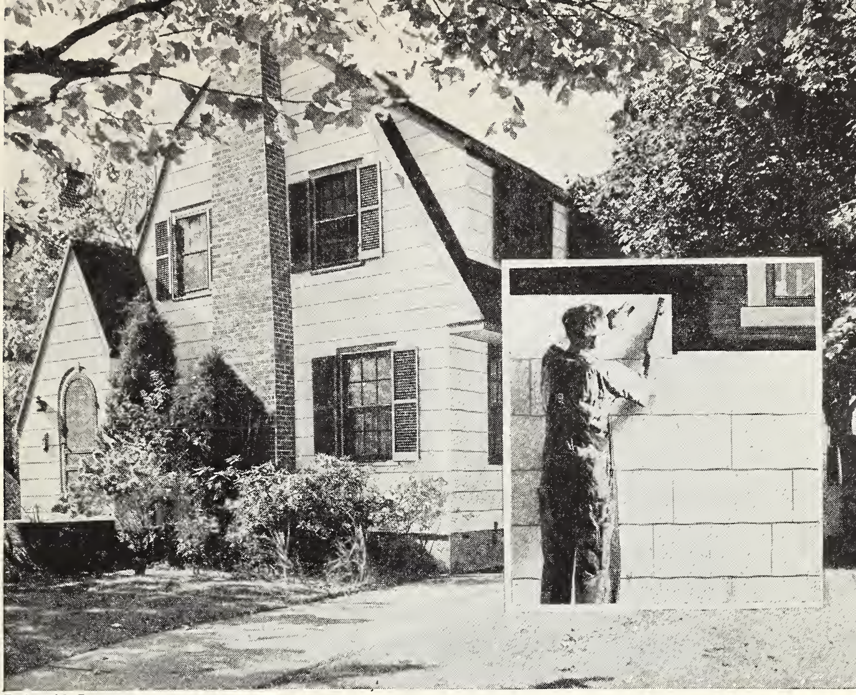
A form of cement is applied to exterior walls as stucco and to interior walls as plaster. Plaster may also be made of sand and lime, mixed at the place of use. Plaster and stucco are supported upon lath. Lath may be strips of wood or a wire netting. The wet plaster is laid on the lath with a trowel [a flat blade] or by compressed air. It flows into the spaces behind the lath and locks itself into place as it hardens. Masonry cement is used to hold together tiles, bricks, concrete blocks, glass blocks, and stone.

How is glass made? One kind of glass is made by melting together, at high temperatures, sand, lime, and washing soda. Other materials may be added to give color or special properties. The melted glass may be poured into forms for making blocks, or it may be poured on a long table and rolled out, polished, and formed into plate glass. The ordinary, uneven glass we use in windows is blown into large bubbles by machines, and the bubbles are cut and flattened out while hot. Glass blocks are made in two pieces, and the pieces are melted together. They are hollow.

Glass is ordinarily brittle, but by special processes of a slow cooling called annealing, it is made strong and elastic enough to be used in springboards.

How are brick and tile made? Modern brick is made from pure clay, moistened and worked to make a heavy, uniform mass. The moist clay may be pressed through openings the size of a brick, so that it comes out as a thick ribbon. The ribbon is then cut into blocks to form the bricks. Individual bricks may also be pressed into molds. The uniformity of the moistening process is a determining factor in producing any good brick. The bricks are placed in kilns and heated until the clay is baked into a hard, rocklike material.

To make tile, a pure, white clay is formed into bricks. Then a glaze is added and baked on the surface of the tile. Color may be



Ruberoid Company

Asbestos may be made into sheets and applied to the outside walls as siding. It may be used on either new or old houses.

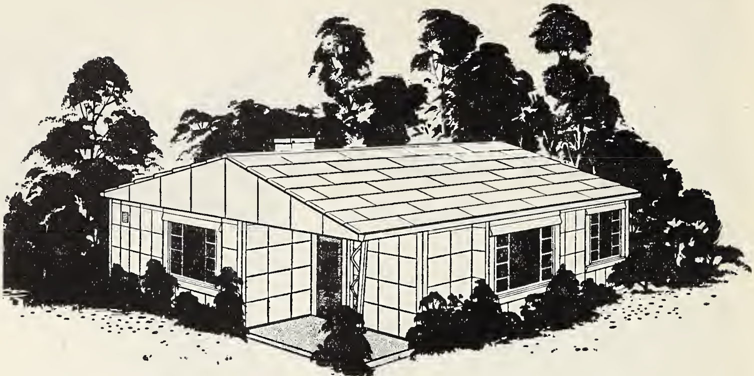
added to tile in the glazing process.

Brick is used for foundations, for chimneys, for lining furnaces, for walks, and for entire houses. Tile is used in finishing bathrooms and for decorative effects. Porcelain, a fine grade of tile, is used in making toilet flush tanks, bowls, bathtubs, and sinks.

What are mica and asbestos used for? Mica is a mineral which occurs in nature as thin transparent sheets. It is used in electrical instruments for insulation against electricity. It is also used in houses for heat insulation. The mica for insulation is heated and expanded much as corn is popped. The expanded mica looks almost like cork, and when used for insulation it is poured between the walls.

Asbestos is another mineral that is used for insulation. It occurs naturally in white, fibrous rocks. The fibers when separated are blown loosely into walls or made into quilts or pressed into paper. Asbestos shingles, made by pressing the asbestos into boards, are extremely durable and fire-resistant.

How are metals used in building? The average small house contains about four tons of met-



Lustron Corporation

This five-room house is made of porcelain enameled steel. It requires no painting, decorating, or re-roofing. It is constructed entirely at the factory and assembled on a concrete slab foundation.

al. This consists chiefly of the heating system, the plumbing, the nails and screws, and the hardware. Most furnaces are made of iron or steel. Water heating coils are often made of copper. Radiators and heating pipes are usually of iron. Pipes of hot air systems are of galvanized iron. Steel is used for frames of most larger buildings. Even in smaller buildings, iron or steel I-beams are used to support heavy portions of the house that do not rest directly upon the foundation.

Copper is used for most electrical wiring, and makes very good roofing and heating coils. Aluminum is used for roofing, for it is an excellent reflector of heat, and is used in the form of foil for insulation or reflecting material in walls. Steel, aluminum, magnesium, and brass are used for window frames and for doors. Lead is used in sewer connections.

Entire houses may be made of metal. Various kinds of panels go into their construction. Some panels are used to form solid walls. Some are used for making floors. Some panels contain windows or doors, and some have plumbing built in. All the panels are bolted together on a foundation and the house is ready.

DEMONSTRATION: HOW ARE MINERAL MATERIALS MADE AND USED?

What to use: Cement, sand, gravel, cinders, cardboard boxes, samples of glass, wood, stone, metal.

What to do: Mix two batches of concrete, one using gravel and the other cinders. After the samples have hardened in their forms test for weight, resistance to absorbing water, and strength.

Place samples of building materials on a hot radiator. After a few minutes feel them with your fingers. The ones which feel warmest are the best conductors.

What was observed: State what the results of the experiment were.

What was learned: Which materials are good and which are poor conductors of heat? What are the advantages and disadvantages of using cinders in concrete?

Exercise

Make a table by ruling your paper into eight columns. Head the columns as follows: INSULATION, HARDWARE, WALLS, FLOORS, ROOFS, HEATING SYSTEMS, FRAMES AND SUPPORTS, WINDOWS. *In each column write the names of several materials used to construct the parts of houses which head the columns. One material may be used several times.*

4. How are functional houses planned?

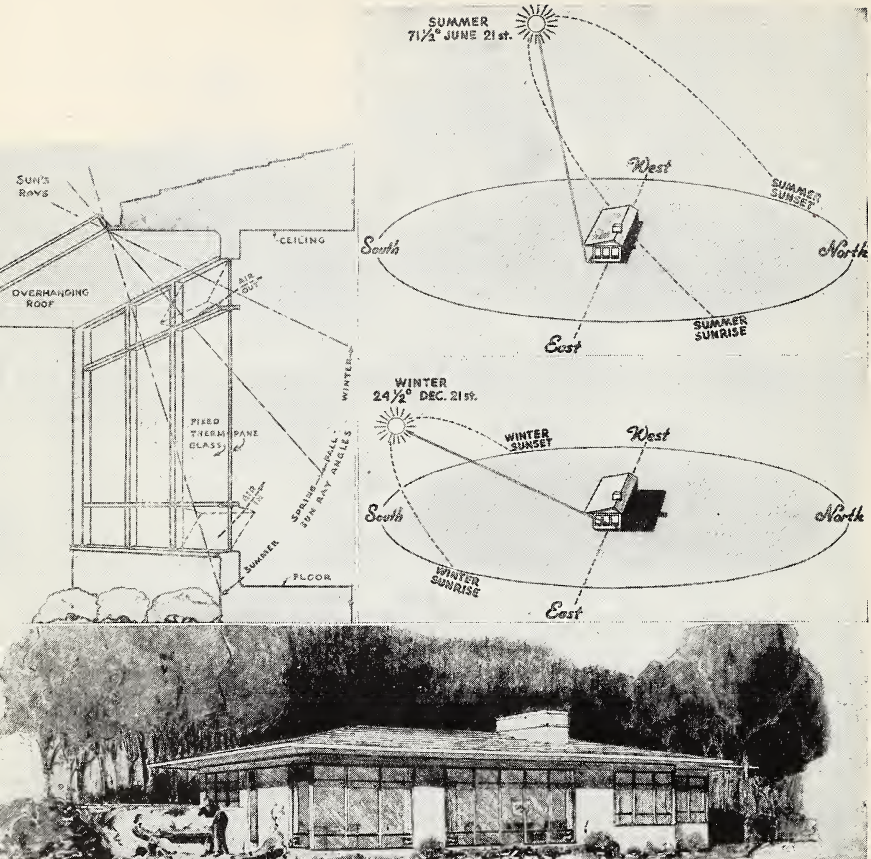
A complete house plan is a complex chart showing arrangement of space, use of building materials, location of all fixtures, and a complete explanation of the construction of a house. The first thing decided is the amount of space required and what can be spent for it. From that point on, there is little limit to the variety of houses that can be built. Most people start out wrong with an idea as to style of exterior they want and have few ideas about their real needs.

How is cost figured? The amount of space enclosed in a house in part determines the cost. The total number of cubic feet multiplied by the cost per cubic foot gives an approximate idea of final cost. Housing costs from fifty cents to a dollar or more a cubic foot, depending upon kind of materials used and upon what is included in the cost.

The average family can afford a house costing about twice its annual income, which makes the chief need for houses costing from $4000 to $10,000. Only one family in ten can really afford the houses pictured in most magazines—the ones costing $10,000 or more. Houses generally rent for 1 per cent per month of the sale price. Until cost of housing is brought down greatly, most people will be poorly housed.

How are houses planned? The first need is to decide what is absolutely necessary, kitchen, living room, bedrooms, bath. Then when cost is a factor, these are made as compact as possible for economy. If money is available more rooms may be added. Bedrooms should be provided for each one or two members of the family, according to age and sex. Storage space, space for heating plant, laundry space, and halls must be included.

To provide a given number of rooms, it is cheaper to build a house of two stories than of one. By making the roof so low that it cuts into the corners of the upstairs rooms, a little money can be saved. A one-story house costs



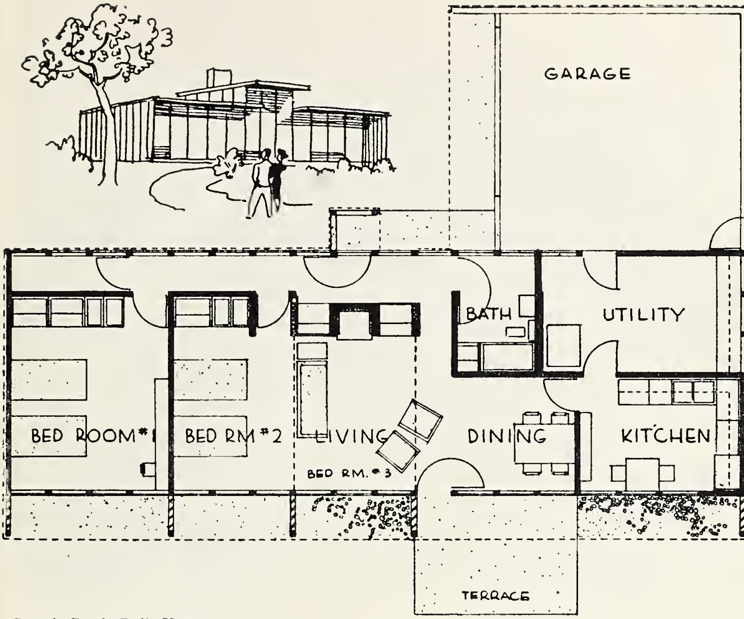
Libbey-Owens-Ford Glass Company

At the top left is a house with a solar window made of double glass and with an overhanging roof to protect against summer sun. At the top right is shown the difference in elevation of the sun in June and December at Chicago. Winter sunshine falls far into the rooms, heating the house enough to save much fuel. Below is the south side of a solar house.

about 5 per cent more than a two-story house, but has the advantage of being more convenient, easier to paint, and safer because no stairs are necessary.

The more nearly square a house can be built, the lower the cost. The so-called rambler, with its rooms spread far apart, may cost 50 per cent more than a house with the same number of rooms compactly arranged.

A basement is an economy in the north, where the foundation



Green's Ready-Built Homes

The solar house plan provides that all important living space may face south. The south wall is made of windows. This particular plan provides a sliding wall between the living room and a bedroom, providing more sleeping area than usual in a small house.

must extend into the ground below the frost line. It costs little more to remove the earth, and to obtain enclosed space, than to dig trenches for the foundation. Basements are unsatisfactory in some regions of the south where they become too humid. Good ventilation should be provided beneath houses when no basement is used in humid climates. In the dry southwest a basement is unnecessary, for clothes usually can be dried outdoors and only a small heating plant is needed.

What are good room plans? An oblong kitchen, with the sink, stove, and refrigerator arranged in the shape of an L is the most efficient of standard arrangements. Cabinets are placed around the corners between the three fixtures. A work table is placed in the open space inside the L. A woman must still learn how to save steps and to work sitting down when using an efficient kitchen.

It has been found most efficient for use to place each of the three essential bathroom fixtures in separate booths opening into a hall. In this way one member

Celotex Corporation

Pellets of a mineral fiber are blown into the spaces of the attic floor to provide insulation.

of a family may take a shower without inconveniencing other members of the family. The shower stall has space for hanging clothes and a stool to sit on while dressing. Such an arrangement is more costly than having all fixtures in one room but much less costly than two bathrooms. In more expensive two story houses it is convenient to place a toilet and a washbowl downstairs, and a complete bathroom upstairs. Placing a washbowl in each bedroom has some advantages.

Bedrooms should be built with sufficient space for beds. In order to provide wall space the door should open in a corner. If windows are placed high and near a corner, they provide good light for a dressing table, and cross ventilation without a direct draft on the bed. Windows high in the wall provide privacy in most situations. Many functional bedrooms have locker-type closets along one wall.

What living space should be provided? The living room may be a combined recreation room, dining room, and place for receiving guests. Or a separate dining room may be included at higher cost. Since a dining room is used only an hour or two a day, if one is included it should be equipped for some other use, such as study, sewing, reading, or

as a general workroom. The typical dining room with its highly polished table, its fragile chairs, and its delicate dishes and silver is generally a highly expensive decoration. In a functional house equally attractive furniture adapted to several uses may be put in the dining room.

In the warmer regions the living room should be combined with an outdoor living area. In the north it should be possible to unite the living room with the outdoors in summer, and to shut out the cold in winter.

What about storage? Modern closets are shallow and fitted for particular uses. The old-fashioned deep closet without a light has never been convenient. Many modern living rooms have cabinets along the walls. All modern kitchens have many cupboards and cabinets. Basements may be used for storage of many things. Space in a closet attached to the garage provides storage for garden tools, the hose, the lawn mower, and wheeled cart.

The bathroom requires storage space for soaps, cosmetics, shaving materials, towels, medicines, and first-aid and home-nursing equipment.

Can you recognize a bad plan? A badly planned house is easy to recognize. The living room may serve as a runway for traffic. Doors open in inconvenient places. Windows are located where furniture should be placed. Cold winds blow into living spaces in winter from open doors. People lack privacy and places to read and work. Useless things are built on the house, false gates, dormers, overhanging eaves, porches, false shutters, pointed gables, false balconies. A bad plan includes things which are useless or inefficient.

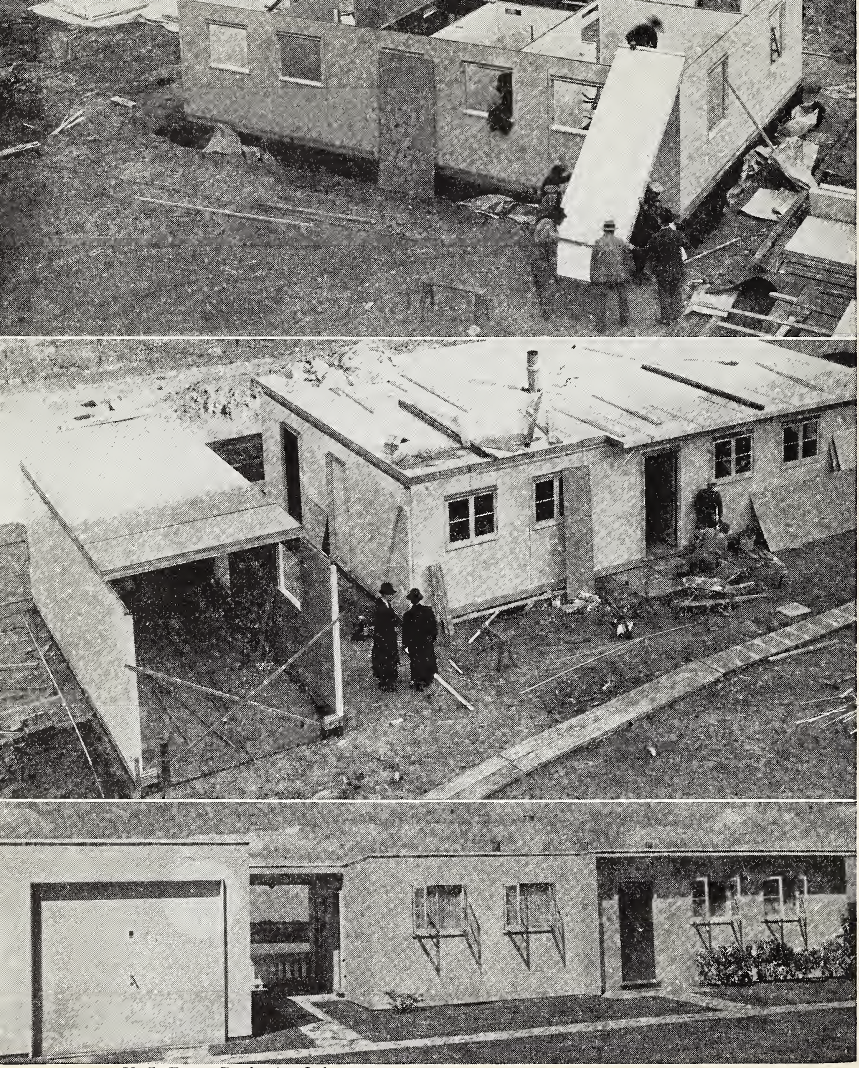
Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: ESSENTIAL, DESIRABLE, LUXURY, UNDESIRABLE. *List in the proper column the following words*: bathroom, kitchen, living room, slate roof, many doors, stairs, dining room, one bedroom per person, laundry, furnace heating plant, stone gate on house, brick court, cross lighting, large windows, sunroom, shutters, fireplace, pantry, insulation.

5. How is the good house constructed?

The good house is so constructed that it offers the greatest possible amount of protection to those who live in it. It must protect not only from cold but also from excessive heat. It must protect against uncontrolled drafts, dirt, and noise. It must offer protection from rats, mice, flies, mosquitos, ants, and termites. It must resist strong winds, fire, and earthquakes. It must be easy to clean and must require little upkeep. Unfortunately there are few houses constructed which meet all these requirements because of cost.

Where is heat lost? Heat is



U. S. Forest Production Laboratory

Much of the work of building a prefabricated house is done in the factory, and the parts are assembled on the foundation. Prefabricated houses may be of wood, plywood, or metal. In the top photo, the plywood walls are in place; next, the roof and windows are added; and below, the finished house and garage await their new owners.

lost in three ways: by radiation, by conduction, and by convection. Radiant heat travels from all hot objects in straight lines

Time Industries, Inc.

A picture window should be used only where the view is pleasing. It should not be placed in such a way as to put family living into a show-window to be observed by passers-by on the street.

through space. The amount of heat radiated depends upon the temperature of the hot object. Heat travels by convection currents in liquids or gases. Air rises above hot radiators and falls beside cold windows because of convection, carrying heat from the radiator to the window. Heat is conducted as it travels along materials, or from one object to another by direct contact.

Radiant heat is lost from all hot surfaces and more rapidly from dark than from polished surfaces. Heat is conducted to some extent by all materials. Heat is also lost by convection caused by air movement within the house, and by winds from outside the house. It is estimated that on a windy winter day wind pressure changes the air in the average house quite completely every two or three hours, with all doors and windows closed. The air leaks through pores in wood, brick, or concrete and through cracks.

Heat is lost about equally from the roof, from the walls and floors, and from windows and doors.

To prevent loss of heat

through the roof, old-fashioned houses have an attic to provide a dead air space for insulation. An attic is a poor insulator. Effective insulation may be placed on the attic floor, however. But insulation prevents only conduction. Heat is also lost in convection currents which escape through ceilings and roofs, which are not airtight. Many modern houses have no attic but are built with flat roofs and are well insulated and made water- and airproof. Such roofs may be cooled in summer by running water over them. The water need not be wasted, for it may be used later for the lawn. It is easier to plan a flat-roofed house because with such roofs it is not necessary to fit roof lines and slopes into the plan.

Movement of radiant heat through the roof may be slowed down in various ways. A roof of polished metal is the best reflector of radiant heat, and one painted a glossy white is next best. Ordinary black or dark roofs reach temperatures of 120 to 135 degrees in summer sun and re-radiate the heat downward into the house. Dark-colored roofs lose heat somewhat more rapidly in winter than do light-colored roofs.

Building materials vary greatly in their ability to conduct heat. Giving fir lumber a value of 1.00, the approximate rate of heat loss of a mineral wool is .29, of cork .30, of a fiberboard .33, of pumice concrete block 1.70, of brick 6.0, and of concrete 9.0. Thus fiberboard one inch thick will hold heat as well as a concrete wall 27 inches thick.

The usual method of preventing heat loss from walls by conduction is by use of insulation, either of the fiberboard variety or of the loose fiber type. Either kind is fairly satisfactory if properly installed. Aluminum foil inside walls prevents radiation. An aluminum-surfaced paper is available to use in combination with other types of insulation. Inexpensive houses often are insulated with paper. In insulating old houses the insulation is often blown into the walls. Such insulation may settle and become damp after a time, however. To prevent water vapor from condensing in cold walls an asphalt treated paper is put on the warm-wall side of the insulation. Wet insulation loses heat and causes decay in walls.

Floors are frequently insulated only with paper. Although rugs are used for insulation, they are unsatisfactory for that purpose. Rugs cause more falls than do any other objects in the house and are difficult to clean. Only a vacuum cleaner will clean a rug, even fairly well, and vacuum cleaners are expensive. Rugs must be regarded as makeshift insulators at best. The most satisfactory floor material available is well-laid linoleum or tile. It is superior to wood because of its freedom from cracks and because of its springiness. It is easily washed.

Windows offer a serious problem in heat control. The average

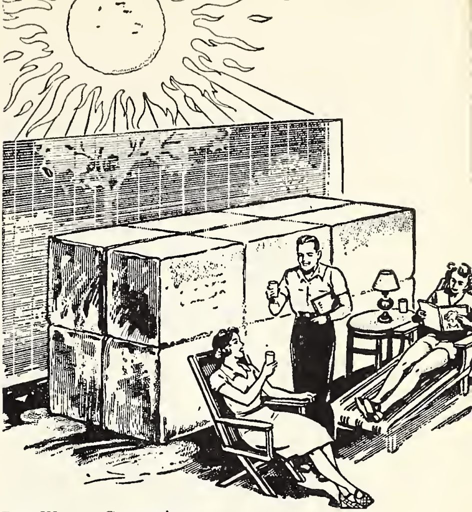
window frame is set into a hole in the wall and held in place by sticks and wedges. Wind blows around any such window which fits loosely in its frame. A single pane of glass radiates heat rapidly and conducts it still faster. A makeshift window insulator is the storm window—a second, cheap-quality window placed outside the regular window. Storm windows are superior to no window insulation, for the inner windowpane is almost 20 degrees warmer in zero weather than if no storm window were used. Weather strips around windows help to prevent heat loss. Windows are generally used for ventilation, but all too often windows ventilate the house whether ventilation is desired or not.

Good windows are made with double panes of glass, which are either sealed or are removable for cleaning. A window made of glass block is highly successful. The block is laid like brick and sealed into the wall. Moisture does not condense on it until the temperature is 15 to 20 degrees below zero. One cannot see through such windows nor open them.

To protect against loss of heat from doors, an entry hall should be provided whenever possible, and both the inner and outer doors should be weather-stripped. The door frame should be sealed into the wall when the house is constructed.

Every rule for keeping heat in applies equally to keeping it out.

It costs about twice as much to heat a poorly built uninsulated house as it does to heat one which is well constructed and insulated.



Borg-Warner Corporation

This special screen reflects the sun's rays. Each 100 square feet of screen on sun-exposed windows gives heat protection equal to use of one ton of ice a day. This screen keeps out insects and does not block the view.

A house well insulated against conduction of heat is also well insulated against conduction of sound. Fiberboards absorb sound waves, and double windows reduce noise from outside.

Are houses easy to clean? The average house cannot be kept really clean. The cracks in the floors, walls, ceiling, and doors leak dust and hold it when it enters the house. Drapes, rugs, and upholstered furniture constantly hold and then give off dust, bacteria, and fibers.

It is possible to build floors that can be satisfactorily cleaned

with an oil mop. It is possible to clean some houses with hot water from floor to ceiling and to dry them, ready for occupancy, when the cleaning is done. Such houses are constructed of brick or concrete, glass, metal, and linoleum or plastics.

The best protection against cockroaches, rats, and mice is an absolutely tight masonry or concrete basement wall, without even a crack in the coal chute or sewer outlet. Flying insects may be kept out by screens over every opening. Both the kitchen and the kitchen entryway should be screened against flies, so that they can be killed before they get into the kitchen. A fine-mesh, copper or plastic screen is desirable.

How are houses constructed? Today houses are not generally bought ready-made. They are built. The time and skill required to build a house is a major reason why our houses are of such poor quality. Each home-builder repeats the errors that have become standard.

Some progress has been made in building ready-to-use houses. Both steel and plywood are used in prefabricated houses. These houses are made in sections and are then set up and joined together in a comparatively short time.

Parts of houses may also be prefabricated and used at a saving of time and money. Windows and doors now are available ready to place in the wall. A unit containing a small furnace, a water heater, and all necessary plumbing has been sold ready to install. Kitchen equipment may be bought all in one unit. Even roof, wall, and floor sections may be bought ready to use.

Factory production of houses should lower cost of housing and should provide work for many more men than are now employed in the building trades. Ten million American families need new houses, and another 10 million probably would buy new houses if they could be obtained like automobiles.

When we compare the efficiency of our machines with the inefficiency of our houses, we realize the cost of failing to apply scientific methods to our everyday problems of living.

DEMONSTRATION: WHAT IS THE EFFECT OF INSULATION?

What to use: Three 250 cc. beakers, two 400 cc. beakers, boiling water, paper, aluminum foil (from candy bar), small board, metal can cover, thermometer.

What to do: Prepare one 250 cc. beaker by wrapping it in paper and placing it inside the 400 cc. beaker. Prepare a second 250 cc. beaker by wrapping it in aluminum foil and placing it inside a 400 cc. beaker. Leave the third 250 cc. beaker unwrapped. Pour about 200 cc. of boiling water into each. Cover the first with the board, the second with the metal cover, and leave the third uncovered. After 10 minutes measure the temperature of each beaker of water.

What was observed: Record the temperatures.

What was learned: Which method of insulation was superior? Is insulation superior to no insulation? What was prevented by the insulation? Can you apply this result to house insulation?

Exercise

Complete these sentences:

—1— is any material placed between walls to prevent loss of heat. Dead air is a good —2—. Insulation prevents loss of heat by —3—, aluminum foil by —4—, and sealing doors and windows by —5—. Floors properly —6— do not need rugs. When it is zero outdoors, the inner pane of two panes of glass is —7— degrees warmer than a single pane. A roof should be —8— in color.

6. What is good house lighting?

Newer houses are light and cheerful. Entire walls are of glass, and indoors and outdoors are together part of the living area. To use the solar window (p. 382) for both light and heat, it is necessary to build the house with the living area facing south. A solar house reduces eyestrain, saves fuel, and is attractive. It is difficult to place on a narrow city lot to obtain privacy and clear southern exposure. But most houses have windows too small, too few in number, and poorly placed.

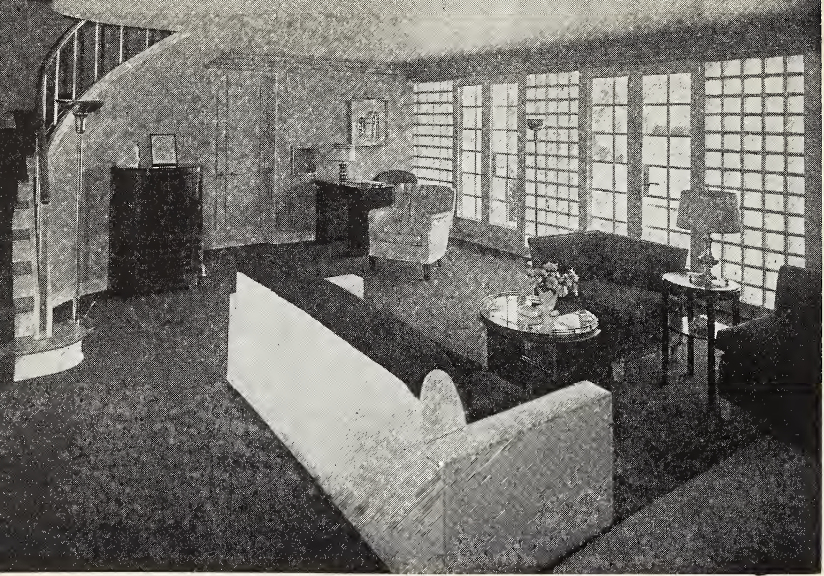
How large should windows be? There are quite definite rules for proportions between window area and floor area, although these rules may not mean much. On a dark day ordinary windows will not provide enough light. On a bright day a small window area will provide more light, if it is properly diffused, than is needed.

When the sky is full of flying clouds, the brightness of light at a window may change in a few seconds from two foot-candles to more than 2000 foot-candles. Direct sunlight causes glare spots which cannot be controlled by ordinary shades and curtains.

The rule is that the clear glass of the window should be equal in area to one-fourth of the total floor area. That is, a room 12 by 18 feet has a total area of 216 square feet. One-fourth of 216 is 54. An ordinary window is $2\frac{1}{2}$ feet wide and 5 feet high. More than four such windows are needed for a 12-by-18-foot room, if no curtains or drapes are used.

Where should windows be placed? Windows should be placed so that they throw light evenly into the room, and in such a way that they do not cause glare. They should protect privacy in bedrooms and bathroom, and should not block placement of furniture. They should be placed to give light where it is most needed. In the kitchen windows above the sink, stove, and work table are desirable.

If the living room has an entire wall of glass it is no problem to place furniture. Chairs, davenport, and work tables are so placed that light falls from be-



Owens-Illinois Glass Company

This wall of glass blocks and the French doors make this a well-lighted room. What sources of glare do you see in the picture? Are French doors satisfactory in the North? Find the four lamps.

hind the person using them. They need not be placed tightly against the window. With ordinary windows, light should be arranged to come from one side of the room. In too many living rooms it is impossible to find a place to read without facing a glaring window.

Bedroom and bathroom windows of the casement type, placed high enough in the wall, give considerable privacy. Furniture can be placed beneath such windows. The ordinary window in a bedroom is almost useless for light, because shades must be drawn when one is dressing. Bathroom windows should have frosted glass panes.

Dormer windows are inefficient, for most of the light is absorbed by the walls of the dormer. Bay windows are no more effective than the same window area placed flat in the walls. The wrap-around window—one placed at a corner—is a novelty and not a great improvement over ordinary windows. If a window is to be used for lighting, it should not open on a covered porch. There is not enough light available from a porch to justify the cost of the window.

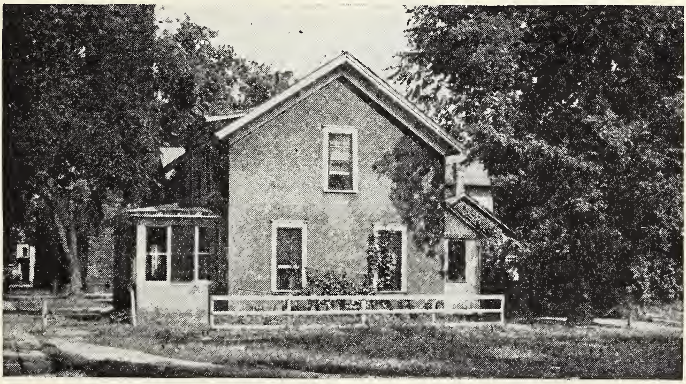
How may light be controlled? The means of controlling light in general use are really methods of shutting it out. The following experiment, summarized in the table, was performed by placing a light meter on a table three inches from the sill of a west window on a bright day.

CONDITION OF WINDOW	BRIGHTNESS OF LIGHT	
	10:30 A.M.	1:50 P.M.
Window bare and open	**90 foot-candles**	**3,875 foot-candles**
With black wire screen	**38 foot-candles**	**1,125 foot-candles**
Plus window closed	**32 foot-candles**	**865 foot-candles**
Plus net window curtain	**18 foot-candles**	**250 foot-candles**
Plus awning lowered	**7 foot-candles**	**16 foot-candles**

This table is interpreted as follows. A black wire window screen reduces brightness of the light from 90 to 38 foot-candles, while closing the window in addition reduces the effective brightness to 32 foot-candles. Then, with screen and window closed, putting a curtain over the window reduces the light to 18 foot-candles. You can interpret the rest of the table with this information. The amount of light in the average living room, with the shades lowered halfway and curtains and drapes over the windows, when no sun shines directly into the room, is less than two foot-candles. This is not enough light for any kind of close work or even enough for cooking and ordinary housework.

Our window shades are placed upside down for effective light control. The best light comes from the upper part of the window, yet this is the part of the window we shade first. Window shades should be mounted at the bottom of the window and pulled upward by a cord passing over a pulley.

A window curtain does not diffuse light well and absorbs from one-fourth to three-fourths



The typical small house is poorly lighted. The windows in this one are badly placed, some of them opening on a closed porch. Shades are drawn from the top of the windows.

of the light. A window of frosted glass would admit 80 per cent of the light and diffuse it satisfactorily.

The Venetian blind is at present the best device available for controlling light. The slats should be either a light color or flat white to reflect light upward to the ceiling of the room. It would be better to place a durable, built-in Venetian blind or shutter outside the window, if means could be devised for controlling it from inside the house. A shutter absorbs heat before it gets inside the house, while a window shade absorbs heat inside the house where it is not wanted in summer. Venetian blinds made of a plastic are now available for interior use.

Drape curtains which lie against the wall, without covering the window except when in use for that purpose are satisfactory for controlling light. For the solar window a stage-curtain type drape is the best shade. It regulates light, provides privacy and keeps in heat at night. The usual useless, decorative, light-absorbing drape has no real value in the functional house.

What is the best wall and ceiling color? The importance of using light colors in decorating the house cannot be overemphasized. A room with one window and cream walls and white ceiling is actually lighter than the same room with four windows if the walls and ceiling are painted blue or green. Since windows waste heat and are expensive to install, it is economical to use all the light that can be admitted from a smaller number of windows.

Dark walls increase glare by increasing contrast between the dark parts of the room and the source of light. To face a window in a dark wall produces considerably more eyestrain than to face a window in a cream-colored wall. The amount of color used in interiors should be held to a minimum.

DEMONSTRATION: HOW DOES COLOR AFFECT REFLECTION OF LIGHT?

What to use: Well-lighted room or projector or beam of sunlight, light meter, white paper, boards painted various colors or colored paper, wall paper samples, color wheel with disks and motor.

What to do: Set up the white paper so that it reflects about 50 foot candles of light to the meter. Do not let stray light enter the meter. Then in front of the paper put a board or piece of colored paper and take a meter reading. Take a reading from the white paper before and after measuring reflection from each color to be sure that light conditions do not change. Be careful not to shade the paper or colors as you work, and do not measure glare from shiny paint.

Set up and operate the color wheel according to directions. Mix various colors with each other and with black and white. A color mixed with white is a tint, with black a shade.

What was observed: Record readings from the white paper, and each colored board or paper. Assume that

the white paper reflects 80 per cent of the light. Calculate the per cent reflected by each color.

Report your impressions of colors which are mixed. Do you see colors as they are?

What was learned: If a room painted flat white requires four windows, how many windows would be required to provide an equal amount of reflected light in a room painted or papered with each color. Explain the principle: The color of an object depends upon the kind of light it absorbs and reflects. Should you use shades or tints in house decoration?

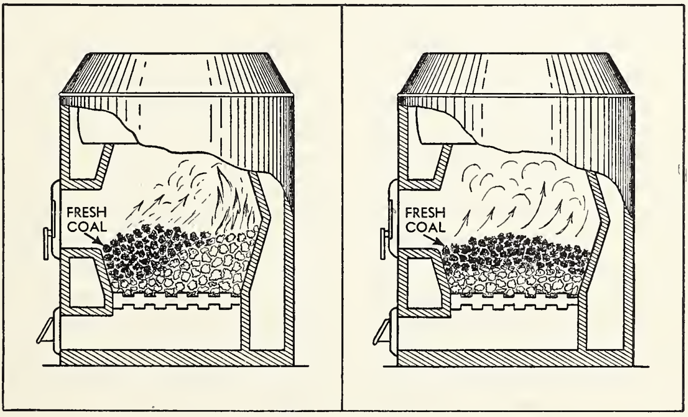
Exercise

Complete these sentences:

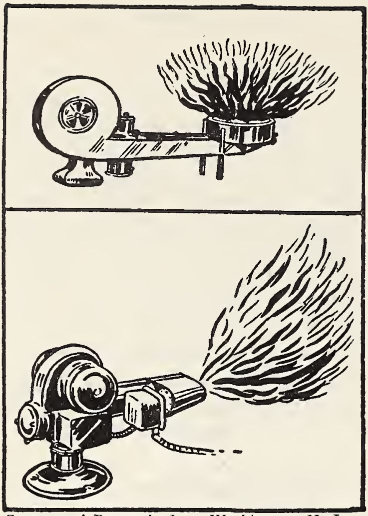
A room with 200 square feet of floor area should have a window area of —1— feet, which is equal to —2— windows, 2½ by 5 feet. The amount of light coming through a black wire screen, at an angle, is about —3—% of the light that comes through a bare window. Light reflected from the floor causes —4—. Ceilings should be —5— in color. Windows should be placed in the upper —6— of the wall. Curtains do not —7— light as well as frosted glass does.

7. How is heat obtained in our houses?

Today there are many ways of heating our houses. We may use the heat of the sun entering through solar windows. We may burn coal, wood, oil, or gas in many kinds of stoves and furnaces. We may burn gasoline in quart-sized heater. We may take heat from the cold outside air, or we may generate electricity from wind. But in the old houses in which most of us live we still



In the correctly fired furnace (*left*), smoke from the fresh coal is burned by flames from the hot coal in the back of the furnace. Incorrect firing (*right*) smothers the hot coals and permits unburned gases to escape through the chimney.



Consumers' Research, Inc., Washington, N. J.

The oil burner at the top causes oil to vaporize in a pot-shaped burner. The one at the bottom mixes a spray of oil with a blast of air from a fan.

depend upon ordinary stoves or furnaces for heat.

The selection of a furnace is determined by the amount of money one has to spend, by the cost of fuels in his community, by personal preference as to how the work of firing is done, and by the efficiency of the various types of furnaces. Furnaces may be classified according to the kind of fuels they burn, by the manner in which they are fired, or by their location in the house.

Why is a stove used? In most houses which cost less than $5000 a stove is the standard heating system. Stoves are used in somewhat more expensive houses in the South than in the North, because in the South heating is required for a smaller part of the year and a furnace is not so essential. When the cold season ends, the stove is removed from the house. Stoves may burn wood, coal, fuel oil, or gas.

The chief advantage of a stove is its low cost. The disadvantages are numerous. Fuel with its attendant dirt must be brought into the living room. Smoke blackens the walls and ceiling. Heat distribution is generally poor, as only one room is heated by each stove. Most stoves are unsightly in the room.

The circulating or convection heater has a metal jacket so placed around the stove that hot air flows upward by convection between the jacket and the stove. Thus heat is better distributed, for there is no unpleasantly hot, direct radiation from the stove. Coldness of floors is decreased by circulation of hot air in the room.

Why is the coal furnace used? A furnace is a stove which is used to heat air or water to circulate heat through a building. It is usually made of cast iron but sometimes of firebrick or other materials. The bottom of the furnace is a series of bars called a grate, through which air flows and through which ashes fall. There is a draft door below the grate, a fuel door above the grate, and a stovepipe outlet. There is usually a damper in the stovepipe.

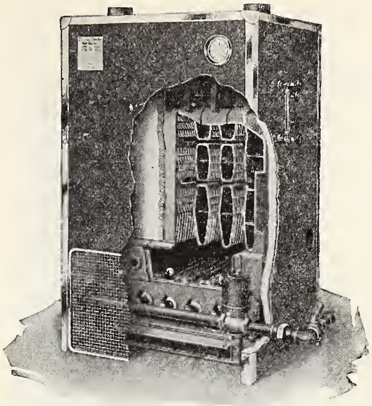
The coal furnace may be fired by hand or by a stoker. When it is fired by hand, the fire is kin-

dled in the usual way, the drafts are set, and coal is added as needed. As coal burns down, a clinker is formed which must be broken up from time to time. Ashes are shaken into the ash pit and must be removed.

When fresh coal is added, it is best to push the hot coals to the back of the furnace and add the fresh coal in front. If coal is added to the top of the fire, it is distilled—that is, gases are driven off which escape up the chimney without being burned. Not only does their loss represent waste of fuel, but the smoke formed is a menace to health and cleanliness. If coal is added in the front of the furnace, the gases pass above the hot coals in the back and are raised to their kindling point.

The coal stoker is a machine that feeds coal into the furnace automatically. The coal is usually driven into the firebox from below. Little coal is wasted, because gases flow upward through the fire and are burned. A stoker usually saves enough coal in a period of 10 years to pay for the cost of installing it. Most stokers are used in connection with forced draft—that is, air is blown through the fire by a fan. To the cost of coal the user of a stoker must add the cost of electricity used to operate the stoker.

Why are oil burners used? One kind of oil burner is somewhat similar to the coal furnace. The oil burner includes an oil pump which sprays oil into the furnace, a fan which provides a



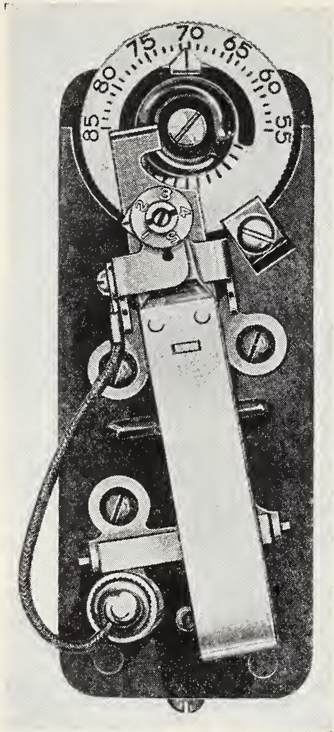
Burnham Boiler Corporation

An essential factor in heating water is to expose a large area of pipe to the flame. The cut-off ends of several pipes are shown.

strong draft of air, and a pilot light or electric device to keep the oil ignited. The oil burner, like an atomizer, mixes oil with air. The fuel used is a low-grade petroleum oil. Another type of oil burner burns the oil in a fire pot, into which oil flows through a valve.

The chief advantage of the oil burner is the small amount of attention it requires. If the furnace is in good condition and the fuel tank is kept filled, it needs no attention. There are no ashes to remove, and there is little soot or dirt from it.

Why are gas burners used? The gas burner is similar to the oil burner in convenience and is simpler in operation than any other furnace. It is essentially a huge Bunsen burner, in which gas and air are mixed and



Minneapolis Honeywell

The thermostat consists of a metal strip, which expands and contracts with the temperature changes, and of accurate controls for regulating the furnace. This thermostat is set to maintain a temperature of 70°.

burned cleanly. The gas burner may be installed in any furnace but is most efficient in a furnace built especially for use with gas.

Gas always presents hazards not risked with other fuels. A broken connection or accidental putting out of the flame may result in violent explosion, poisoning, and sudden death. Gas burners must always be connected to a flue. In fact it is unsafe to use any flame-producing heating device without a flue.

Why is the fireplace undesirable? The fireplace is so inefficient that it has little merit as a heating device. Its use is decorative and sentimental. A fireplace is included in modern homes because of a traditional pleasure obtained from watching an open flame.

How efficient are heating plants? The efficiency of a heating plant is determined by dividing the number of British thermal units liberated from the furnace by the total number of B.t.u. in the fuel. The most efficient of all heaters is the electric radiation coil, which delivers almost 100 per cent of its energy into the room. Gas burners are next in efficiency, ranging from 75 to 80 per cent for burners operated properly. Efficiency of gas burners may be as low as 30 per cent when poorly adapted to the furnace in which they are used.

Oil burners range from 60 to 70 per cent in efficiency. Most coal furnaces which are operated by stokers are about 50 to 60 per cent efficient. Hand-fired furnaces range from 25 to 50 per cent efficient. The fireplace is 5 to 10 per cent efficient.

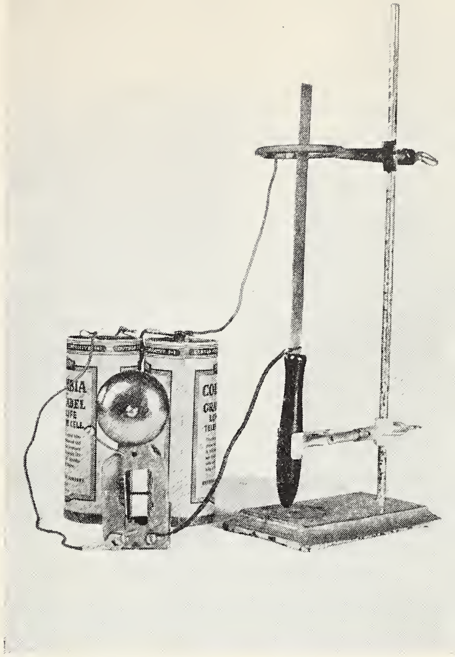
Probably the cheapest heat over a period of years is obtained by using soft coal in a stoker-fired furnace. This cost does not include cost of labor for attending the furnace. It is impossible to set a standard rule for the entire United States, for freight

costs and abundance or scarcity of a given kind of fuel is an important factor in cost.

What is a thermostat? The oil burner, the coal stoker, the gas burner and the drafts of a furnace may be automatically controlled by use of a thermostat [thûr′mô·stăt]. A thermostat is often a metal bar—made of a strip of brass and a strip of iron welded together—which bends as it is heated or cooled. When the bar is cooled, it bends toward the iron; and when it is heated, it bends toward the brass, because of the greater change in brass when it expands. This bar is usually so coiled or bent that it takes up little space. The moving bar may be used to make electrical contacts to turn on the fire when the room is cooled and to shut it off when the room is warm. An accurate thermostat will maintain a temperature range of less than two degrees. It may be set at any desired temperature. Many thermostats have clock arrangements. After a certain hour, heat is turned off in the evening and turned on in the morning. The thermostat controls the motors which control the fires. Thus the operation of the heating plant becomes so nearly automatic that it requires little attention.

DEMONSTRATION: WHAT IS THE PRINCIPLE OF THE THERMOSTAT?

What to use: Compound bar, ring stand, clamp, ring, doorbell, dry cells, wire, burner.



This demonstration apparatus is used to show the principle of the thermostat.

What to do: Arrange the apparatus as shown in the illustration. Wrap the wire from the bell around the blade of the compound bar to make a good connection. Wrap the wire from the dry cell around the ring in such a position that when the blade is bent it will touch the wire. Heat the compound bar with the burner flame.

What was observed: How does the heat cause the bell to ring?

What was learned: What is the principle of the thermostat?

Exercise

Make a table by ruling your paper into five columns. Head the columns as follows: TYPE OF HEATING DEVICE, KIND OF FUEL, HOW FIRED, EFFICIENCY, RELATIVE COST. *Find the types of heating devices*

listed in the text. Use these words to fill in the other columns: oil, wood, coal, gas, hand, stoker, gas and air pressure, pump, burner, costly, cheap, fairly costly. *Find the list of efficiencies in the book. You may use words not in this list if you wish.*

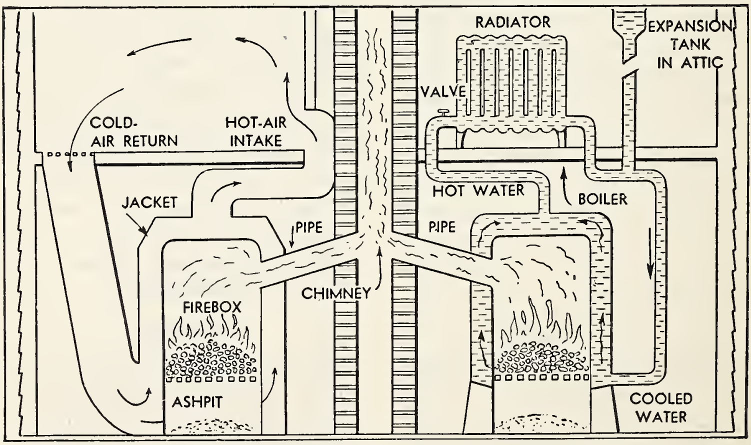
8. How is heat distributed within the house?

Liberating heat from fuel is not the only problem connected with house-heating. It is necessary to carry the heat from the furnace and to distribute it where it is needed. There are three carriers of heat in common use: steam, water, and air.

How does the hot-air system work? Air moves in the hot-air heating system by convection. Since air expands as it is heated, its weight per unit of volume is reduced. The cold air settles, and the warm air rises.

The hot-air furnace is usually located in the basement. Air flows upward into the rooms through large, sheet-metal pipes. There may be one pipe opening directly into the room above the furnace, or there may be pipes leading to and from each room. In the one-pipe, or so-called "pipeless," furnace return air flows down a pipe surrounding the hot-air pipe. In the piped furnace, hot-air pipes carry air from above the furnace to the rooms; the cold-air pipes return it to the bottom of the furnace. Air is thus recirculated many times, because it is not economical to lose the heat immediately. Some fresh air is mixed into the recirculated air through a pipe from out of doors.

If a fan is used to speed up the



These diagrams show how the most common hot-air and hot-water heating systems produce heat and carry it into the living space.

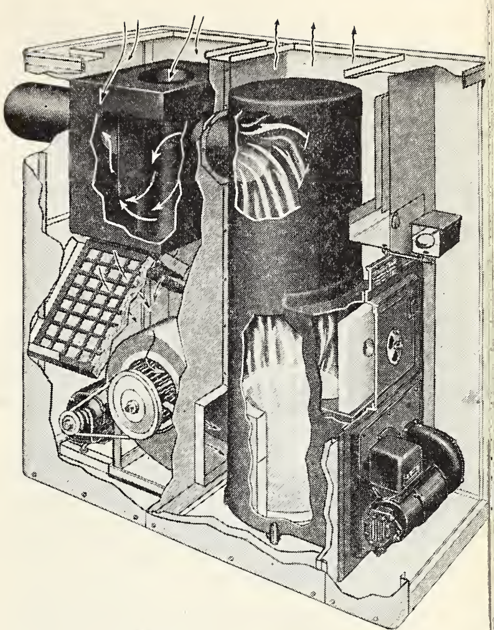
circulation of air, the system is said to provide forced circulation. If differences in temperature move the air, the system is called a gravity or convection system.

The hot-air system is most useful in houses of four to eight rooms. Hot air tends to carry soot and dust from the basement to the living space. Filters may be used to clear the air.

How does the hot-water system work? A hot-water heating system is equipped with a boiler which in small systems surrounds the furnace. The large boiler may be equipped with fire tubes or with water tubes. Hot water circulates by convection, just as hot air does, but is carried by pipes to radiators within the rooms. The cooled water returns to the boiler in another set of pipes. Cold water flows into the boiler at the bottom, and hot water leaves the boiler from the top. Hot-water systems usually are provided with an expansion tank in the attic or an overflow pipe through the roof. This is done so that when the water expands, it can escape without bursting the pipes.

Because water holds heat well, the temperature of the radiator is kept fairly even. This is an advantage in maintaining even temperatures but a handicap in obtaining rapid heating. Heat is released into the room only as the water cools.

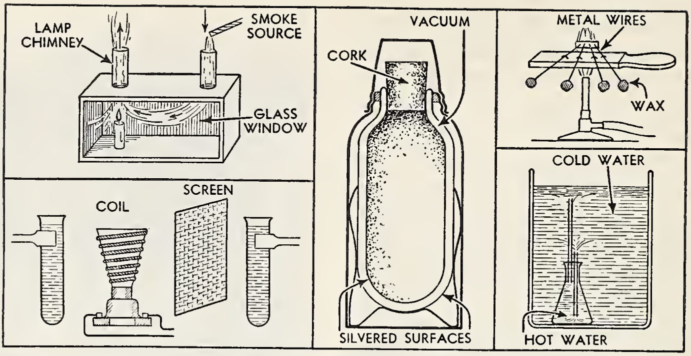
Hot-water systems are generally used in houses of 6 to 12 rooms. The hot-water system heats different rooms more evenly than does the hot-air system.



Round Oak Company

On the right is an oil-burning furnace. On the left is a radiator, filter, and fan. The black arrows show the circulation of air from the room, around the furnace, and back into the room. White arrows represent burning gases.

How does the steam system work? The steam system depends upon the pressure exerted by the steam in the boiler to provide movement of the hot gas and upon a change in the state of matter to release heat. Since heat is required to change water to steam, the heat stored in the steam is given off in the radiator when the steam changes back to



These experimental devices demonstrate the principles of convection, conduction, and radiation as explained in the demonstration on page 403. Set them up and test them.

water. The warming of the room thus depends upon the condensing of the steam. The hot water formed by the steam gives off heat, too.

Steam is generated in a boiler provided with a steam dome in which the steam collects. On this dome are a pressure gauge and a safety valve.

Steam may be carried in a one-pipe system, a two-pipe system, or a two-pipe vapor system. In the one-pipe system, steam flows upward through the pipe to the radiator. The steam condenses, and the water formed trickles down the sides of the radiator, along the bottom, and down the sides of the steam pipe to the boiler. In this system, steam enters the bottom of the radiator.

In the two-pipe system, the steam enters one end of the radiator, and the water flows from the radiator at the other end. The steam enters at a point high enough that condensed water will not cover the pipe.

In the vapor system, the two-pipe arrangement is used, and in addition a pump reduces the pressure in the return pipe, causing steam to flow more readily through the system. The condensed water is forced against pressure into the boiler by the pump.

The steam system of heating is used in all large buildings and in many homes.

How do radiators give off heat? Three factors determine the effectiveness of the radiator. The first of these is temperature. When heat is radiated from one object to another, the rate at which the heat is radiated is in proportion to the difference in temperature. Heat is given off about twice as fast from a radiator at 170 degrees as from one at 120 degrees at room temperature.

The second factor which determines how much heat is radiated is the amount of radiating surface. If two radiators are of the same temperature and one is

twice as big as the other, the bigger one gives off twice as much heat as the smaller.

Because hot water rarely reaches the radiator at 212 degrees, hot-water radiators must be made considerably larger than steam radiators.

The third factor in heat radiation is color and type of radiating surface. A rough, black surface is the ideal radiator, and a smooth, polished surface the poorest radiator. A good reflector is a poor radiator. The practice of painting radiators with aluminum paint decreases their speed of giving off heat.

Steam radiators are equipped with valves to permit air to escape. The valve is essentially a hole into which a needle fits. The needle is pushed tightly into the hole when a piece of metal in the valve is warmed enough to expand. The valve is so constructed that condensed steam drains from it into the radiator.

Many new types of radiators are being developed to improve distribution of heat in the house and to get rid of the bulky, old-fashioned radiator in the room. One type is a hollow pipe which replaces the baseboard. This radiator spreads heat evenly around the room and requires almost no useful space. It may be painted to match walls. Another type, called panel heating, is made up of pipes laid in the floor, the walls, or the ceiling. If a concrete floor is used, the pipes may be buried in the concrete. If enough pipes are used to warm most of the floor or ceiling, providing a large surface, the temperature of the floor or ceiling may be kept comfortably low and still be high enough to heat the house. Behind each radiator a reflector of polished aluminum or foil should be placed. Why?

DEMONSTRATION: HOW IS ENERGY CARRIED FROM PLACE TO PLACE?

What to use: Smokebox, 2 lamp chimneys, candle, touch paper, Erlenmeyer flask, glass tubing, stoppers, battery jar, coloring matter, Bunsen burner, conduction apparatus, electric heating coil, test tubes, cardboard, thermometers.

What to do: Set up the smokebox, as shown on page 402, and test the currents of air at both chimneys.

Fill the flask with nearly boiling colored water, put in the stopper and tubes as shown in the diagram on page 402, and put it quickly into the battery jar of cold water.

Dip each of the four wires in melted wax. When a drop of wax forms on the ends of the wires, heat them as shown in the diagram on page 402.

Set up the coil, cardboard, and test tubes as shown on page 402. Measure the temperature of the water at the beginning of the experiment and after 10 minutes.

What was observed: Describe what happened in each demonstration. What principles are illustrated by each demonstration?

What was learned: Explain radiation, conduction, and convection.

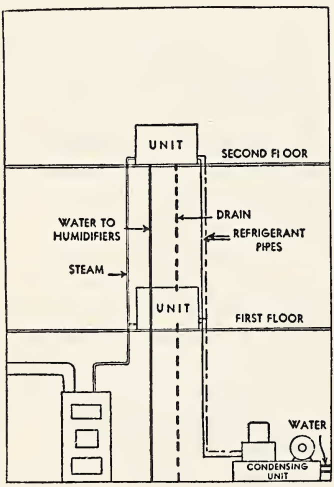
Exercise

Complete these sentences:

The movement of air and water in heating systems is a form of —1— currents. Steam gives off its heat when it —2—. Movement of steam, water, and air depends upon the energy possessed by —3—. The greatest amount of air movement and ventilation is provided by the —4— system. The evenest temperatures are provided by the —5— system. The —6— system is used for a 60-room building. The rate of radiation from one surface to another is in proportion to the —7— in temperature. The amount of —8— determines the rate of radiation. The best surface is rough and —9— in color. Air valves are provided on —10— radiators.

9. How do we maintain good air conditions?

The condition of the air in the house has much to do with our comfort, vitality, and health. A good condition of the air includes a comfortable temperature, correct humidity, a reasonable amount of air movement, and freedom from unpleasant odors, bacteria, dust, and pollen.



Of the many systems of air conditioning, this is one of the commoner. Trace the movement of heat from the rooms, through the machine, and out through the water pipes. Compare this with the electric refrigerator.

What is the best temperature for health? There is no one temperature that is correct for house heating. The amount of activity of the occupants of the house is one factor in determining the need for warmth. Humidity makes a difference in the feel of air, the moister air on the average feeling warmer than dry air. The temperature of surrounding surfaces makes a great difference in the need for warmth, for if one radiates heat to a cold surface, he feels cold, even though the air may be warm. An icy window increases the need for heat in the room.

The season of the year and amount of clothing worn are other factors in determining desirable temperature. In winter clothing, one may be comfortable at 68 degrees, and in summer clothing, at 75 or 80 degrees. In summer there should not be too great a difference between indoor and outdoor temperatures. Then too, some rooms require

more warmth than do others. The bathroom should be warmer than the kitchen. Age, sex, and the vitality of the people who live in the house are other factors.

Generally a temperature of 72 is considered comfortable in winter, and a temperature of 75 satisfactory in summer. The problem of maintaining comfortable temperatures would be simplified and the cost of air conditioning would be reduced if women would wear more clothing in winter and men would wear less clothing in summer.

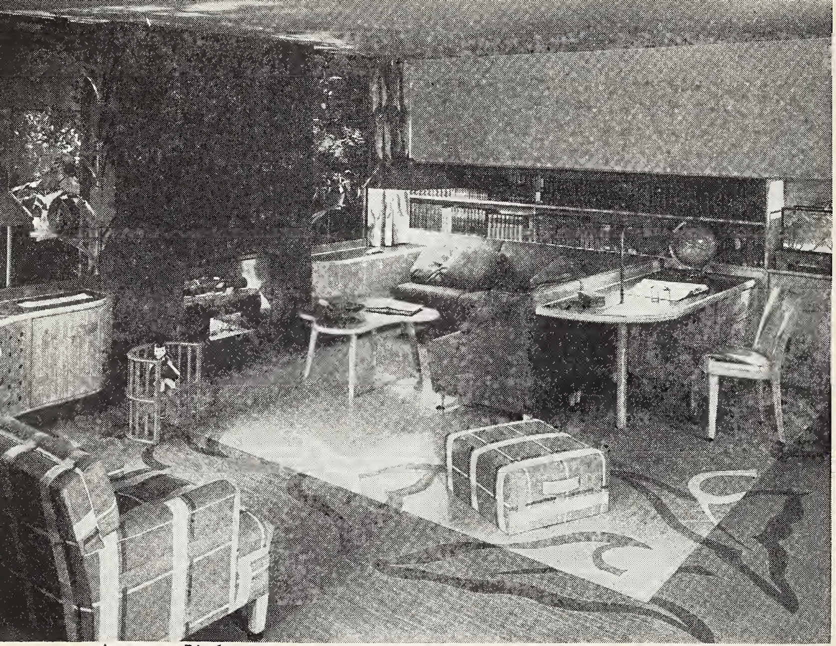
What is the best humidity? Humidity of the air is measured in two ways. Absolute humidity is the amount of water vapor by weight in a given amount of air. Relative humidity is the amount of water vapor in the air at any given time, compared with the amount of water vapor the air would hold if saturated at the given temperature. Relative humidity is expressed in per cent. A relative humidity of 100 means that water vapor is ready to start condensing, for the air holds all the vapor it can. A relative humidity of 50 indicates that the air could absorb an amount of water equal to the amount of water vapor already in the air. A relative humidity of 0, of course, would indicate that the air is absolutely dry.

When the temperature of the air increases 20 degrees, its ability to hold water vapor is approximately doubled. If air at 50 degrees has a relative humidity of 60 and the air is heated to 70 degrees, the relative humidity drops to 30, although no water is taken from the air.

A relative humidity which is too high in the summer causes extreme lack of vitality. Perspiration clings to the body. When the humidity is too low, the throat feels dry and the skin is uncomfortable. If the house is too humid in winter, water vapor condenses on the windows, in the walls, and in the attic. The moisture causes decay and decreases the effectiveness of insulation. A wet blanket is a poor cover for a person or a house. It seems that a relative humidity of 30 is enough for winter. It is cheaper to heat the house to overcome the feeling of coldness caused by dry air than it is to evaporate enough water to increase the humidity.

If air is cooled in summer by blowing it through refrigerating coils or pipes carrying cold water, water vapor must be removed from it. To make air at 75 degrees dry enough for comfort, the air must have been cooled to about 50 degrees to condense the water vapor. The greatest expense in cooling air is the removal of excess moisture.

How do we measure humidity? There are on the market two types of devices which measure humidity. One employs a strand of hair kept tight by a spring. The hair expands and contracts with moisture changes, and operates a needle which moves across a marked dial. This type of hygrometer is relatively inaccurate.



Armstrong Linoleum

Many modern homes have floors of linoleum. It is attractive in appearance, reasonable in cost, and easy to clean. How many features of this room are functional and how many are decorative?

The other type of measuring device employs a wet-and-dry-bulb thermometer. The wick around the end of the wet bulb is kept moist and is cooled by evaporation. The drier the air, the more rapid the evaporation and the lower the temperature of the wet bulb. This device is read by the use of tables.

What is ventilation? Ventilation includes the movement of air and the exchange of air between indoors and outdoors. There are three kinds of ventilation.

Gravity or convection ventilation is obtained by opening a window at the top and bottom. It works only when the temperature indoors is different from that outdoors. The chief objections to gravity ventilation are that it produces cold floors in winter and does not work in summer.

Cross ventilation is dependent upon the wind blowing. When windows are opened on opposite sides of a room or house, the wind blows through and removes the stale air from the room. This method also produces cold floors in winter and may cause drafts much too strong for comfort. Unless filters are placed in openings, dirt is carried into the house through open windows.

Window ventilation seems to be as good for the health as forced ventilation, if comfort is not considered an important factor. Windows that are well placed for ventilation are often poorly placed for light. Functional houses may have special openings in the wall to provide ventilation.

Forced ventilation is produced by using fans. An ordinary electric fan may be used to circulate air in the room or to blow stale air out the window. In winter a fan turned on a hot radiator or stove will relieve coldness of floors and will cause the hot air that accumulates near the ceiling to move down where it can be enjoyed. A fan in the attic will blow warm air from the house in summer.

There are many systems of forced ventilation, but all depend upon use of either the common vane-type fan or the cylinder-shaped fan. Some schools have unit ventilators in the schoolroom; others have air provided from a central system.

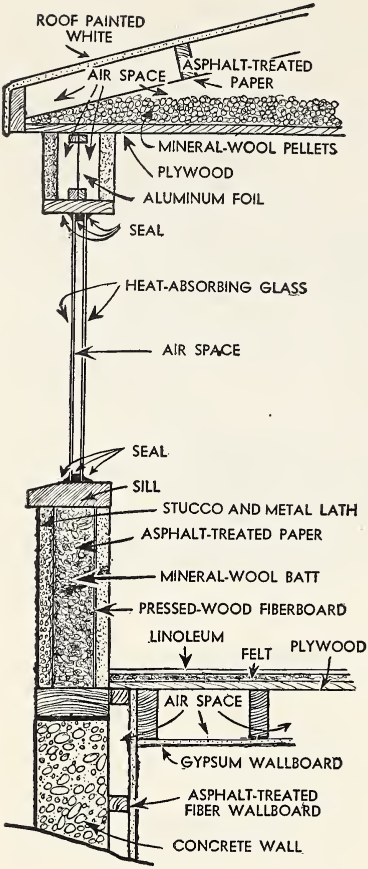
What is air conditioning? Air conditioning provides control of temperature, humidity, circulation, and cleanliness of the air. It includes both heating and cooling air as required.

Air may be humidified by spraying water through a current of air or by heating water in an open tank. Rate of evaporation depends upon the amount of surface, the temperature, and the rate of air movement. When water evaporates, either from the air of the room or from the furnace tank, a certain number of calories of heat are required to evaporate a given amount of water. Evaporating water in the room cools it.

Air may be cleaned by forcing it through wet cloths, through sprays, or through filters. Filters are frequently made of glass wool, moistened with mineral oil. A good filtering system removes from the air more than 90 per cent of such solids as dust and pollen.

Odors are difficult to remove from air. Tobacco odors increase in unpleasantness as the smoke becomes stale for a period of three or four hours. About the only way to remove such odors from the room is to remove the air, replace it, and condition the fresh air as it enters the house.

Air may be cooled by melting ice, by cold water, or by refrigeration machines. Ice is usually used by putting it into a tank and blowing air over it, and then into the living space. Cold water may be used as a spray through which the air is blown, or it may be run through pipes over which air is blown. Water from deep wells is often cold enough to use for cooling air. The mechanical air cooler is an enlarged version of the refrigerator (p. 335). Air is generally blown over the cooling unit and into the living space, but the cooling unit may be placed directly in the room where it is to be used. The condensing coils are usually cooled by water. Small room coolers are



Although no wall or house would contain all these types of insulation, each has its special uses. Can you explain what they are?

placed in windows, so that the air blown from the room passes over the condensing coils, carrying heat from the room.

If air is blown over cold pipes, some provision must be made for getting rid of the water which condenses from the air on the pipes. A cooling system is rated or measured in terms of the number of tons of ice which would be required to produce the same amount of cooling in an hour.

Before air conditioning can be practical, the house must be well insulated and the walls must be moisture-proofed so that the humidity will not rot the timbers or cause insulation to settle. Windows and doors must be tightly fitted. Most houses cannot be air conditioned except at too high a cost. Air conditioning is now a luxury in the small home. It is an important aid to sales in stores and restaurants, however.

DEMONSTRATION: HOW DO WE MEASURE HUMIDITY?

What to use: Wet-and-dry-bulb thermometer with tables, hair hygrometer.

What to do: Operate the devices for measuring humidity according to directions supplied by the manufacturer.

What was observed: What is the relative humidity of the room?

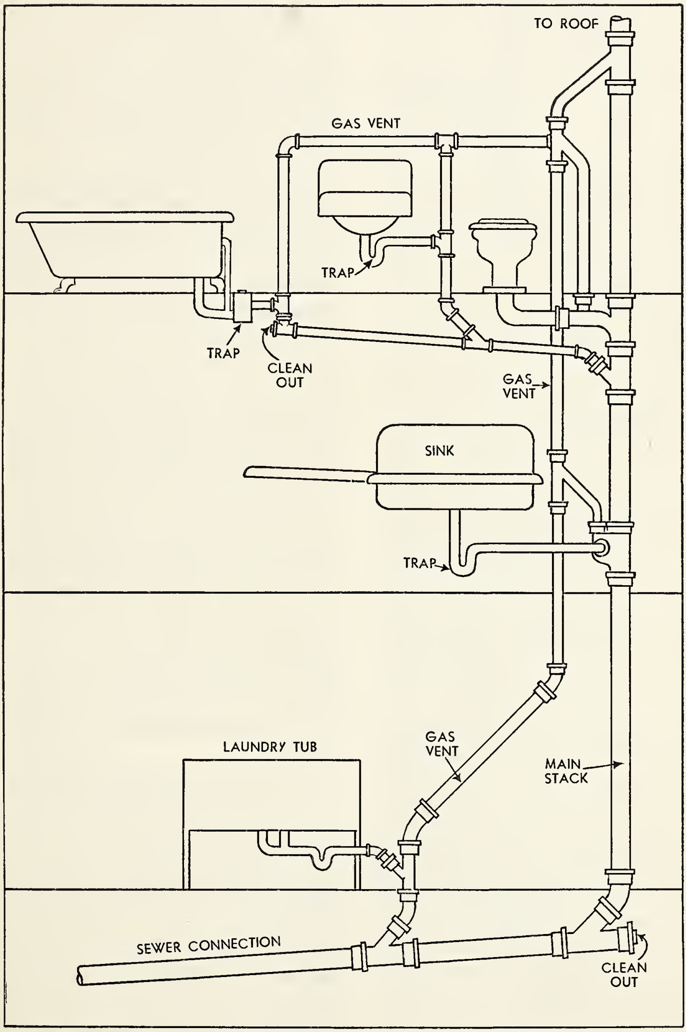
What was learned: State briefly the principles upon which humidity is measured.

Exercise

Write a paragraph summarizing this problem, using in it the following words: temperature, relative humidity, humidity, water vapor, summer temperature, winter temperature, air movement, cross, gravity, forced, air conditioning, filter, condensation, insulation, rate of evaporation.

10. What is safe plumbing?

When water is distributed in the house and wastes removed, we rarely think of the complex system of pipes and equipment necessary to permit us to get along with so little effort. Yet a



The sewer connections must provide an escape for gas, as well as a means of removing waste water. Study this diagram carefully.

child who lives where water must be drawn from a well, carried in a pail, and used with care to avoid causing extra work can hardly understand how water can be used as lavishly as is common in our cities.

What is plumbing? Plumbing is the entire system of pipes which carry water within the house. It includes the hot-water system, the water pipes, the sewerage pipes, and connections to the water main and sewer. In some farm homes it includes a pump and a water tank. Some houses have water softeners or cisterns for rain water. The word "plumbing" is also used loosely to apply to plumbing fixtures, the washbowl, the tub, the sink, the flush tank, and the laundry equipment.

How is plumbing made safe? The first and by far the most important rule to observe in installing plumbing is to make it absolutely safe from the health standpoint. All possible connections between sewers and the water supply must be avoided.

It is possible that a connection between the toilet and the water supply may occur.

The only safe type of toilet flush tank is one into which water runs from a pipe completely *above* the water level in the tank. The supply pipe must not pass up through the water in the tank, nor be connected to the bowl. The amount of cholera, typhoid, dysentery, and other water-carried diseases can be reduced by better plumbing.

The ends of faucets should be well above the water in the washbowl even when the bowl is full enough to spill over on the floor. Water may be sucked up for a height of an inch or two into the pipe of a washbowl on the third floor when the pressure is completely off. Bath spray hoses, if left in the tub, may siphon water back into the pipes.

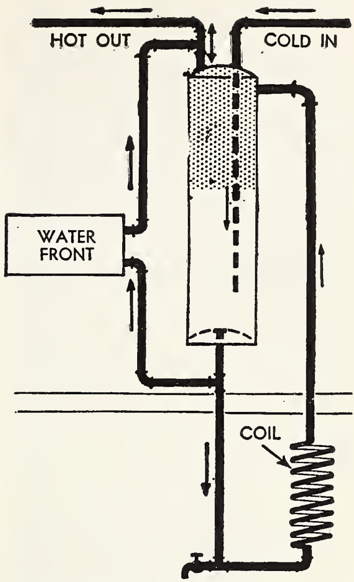
For economy rooms in which plumbing is installed should be close together. If you study house plans, you will find that many houses are not built according to this rule. The most economical arrangement is to have the kitchen and bathroom adjoining, so that the same set of pipes may serve both rooms, entering them from the dividing wall. Next best is to have the bathroom above the kitchen. Not only does this arrangement save pipe, but it avoids the need of filling long cold pipes with hot water from the heater.

In the northern states water pipes should be protected from freezing, for expansion of freezing water is sufficient to burst an iron pipe.

All sewer outlets should be sealed with water in a trap under the fixture. Although sewer gas is not a poison, it has an unpleasant odor. If a vent pipe is connected to the sewer and to each fixture, gas pressure does not accumulate to cause bubbling through the traps.

How does the water heater work? The water heater consists of a tank, connecting pipes, coils,

and a heater. The tank is usually of iron and often is wrapped in asbestos. The coil may be actually a coil of pipe, or it may be a water back or water front in a stove. A coil is usually enclosed in a cylinder of metal and is heated with a kerosene or gas flame from a burner. The flame passes around the coil of pipe. The water front is a flat box against which the flames move. Cold water flows by convection into the bottom of the coil or water front, and hot water from the top into the tank. A tank may be connected to both a stove and a heating coil, as shown in the diagram.



It is possible to heat water in the same tank by more than one heater. The water front may be in a coal-fired range, and the coil may be heated by kerosene or gas.

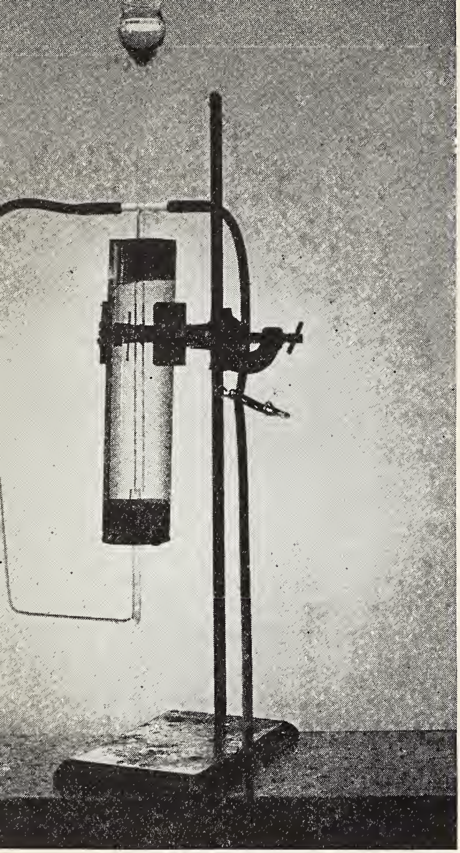
Electric heaters work in two ways. One kind has an insulated resistance coil inside the tank. The other has the heating coil wrapped in an insulated band around the outside of the tank.

The heating of the tank may be regulated by hand controls, by merely building a fire, by a thermostat and automatic heating control, or by a time clock. Each system has some advantages. Automatic controls usually require electricity.

What fixtures should we select? The type of fixtures one buys is determined by the amount of money available. The important factor is that they be sanitary. The bathtub should be one that can be easily cleaned, and it should be fitted to meet the floor. The kitchen sink should have a drainboard and should be smooth enough to clean easily. All faucets should be well above the water level of the fixture when it is full of water.

A shower bath is superior in convenience to a tub. It is possible to wash in clean water in a shower. By being careful, a shower can be taken with less water than is required to fill a tub.

How can we keep plumbing clean? The cleaning of porcelain plumbing fixtures is usually done too vigorously. Most scouring powders scratch the surface and cause microscopic grooves which fill with dirt, causing slight but permanent dulling of the color or surface. A better method than using scouring pow-



Arrange the demonstration apparatus as shown here.

der is to use a mixture of nine parts whiting and one part tetrasodium pyrophosphate. These materials may be bought through paint and chemical supply stores and will clean new surfaces effectively. For surfaces already scratched, scouring powder is required. Remember that the faster a cleanser cleans, the more it is likely to scratch.

To keep sewerage pipes open, avoid putting materials into them that do not dissolve or decompose readily in water. Neither cloth nor cardboard should be put into the toilet bowl. Unless garbage is finely ground by some device such as the "electric pig" it should not be run into the kitchen sink drain. One of the good investments in any home is an incinerator for burning wastes, if regular garbage service is not available.

Soft water reduces clogging of pipes by soap scum and grease. It is well to flush out traps and drains occasionally with several gallons of boiling water.

Every properly installed drain has a cleanout opening which is closed by a screw-in plug. This plug can be removed so that any obstruction may be twisted or pushed from the pipe by use of a long, flexible steel spring. You will find the proper location of cleanouts in the diagram on page 409. Most traps have cleanouts at the bottom. In loosening cleanout plugs, they should not be twisted too forcibly, for broken threads cause leakage.

DEMONSTRATION: HOW DOES THE WATER HEATER WORK?

What to use: Argand lamp chimney, a one-hole and a two-hole stopper to fit, glass T-tube, thistle tube, glass and rubber tube, ring stand and clamp, burner, pinchcock or clothespin.

What to do: Set up the apparatus as shown in the illustration on this page. Fill the lamp chimney with water. With the mouth withdraw air from the outlet tube, and when there is no

air in the tubes, close the outlet with the pinchcock.

Heat the glass tube with the burner, being careful not to heat it too rapidly. If you wish to show currents more clearly, put a few drops of ink in the thistle tube. When the water seems hot, permit some to run from the delivery tube. Be sure to maintain the level of water in the thistle tube as needed.

What was observed: Describe the action of the heating tank, or draw a diagram of it.

What was learned: Is the heating tank a special use of convection currents? Explain.

Exercise

Complete these sentences:

The system of pipes by which —1— is supplied to the house and —2— is carried away is called —3—. Flow of water is controlled by valves and —4—. —5— is kept out of the house by traps. There must be no connection between the city water and the —6—. Water is heated when it flows through —7— passing through a flame. The water circulates because hot water is —8— in weight than an equal volume of cold water. This movement of water is called —9—. If water pipes are light in color or polished they do not gain or lose heat by —10— so rapidly.

A review of the chapter

To build our houses for greatest comfort, we must be able to apply the sciences of physics and chemistry in selection of materials; the laws of heating in selecting a furnace and in constructing and insulating the house; the laws of lighting in placing windows, selecting lighting equipment, and painting the house; the use of measurement in planning the house; and the laws of sanitation in making it safe.

Most of the older houses show little application of scientific laws in their construction. To improve our houses, we need better planning, better use of materials, and more general education of the public and the builders regarding the inefficiency of the older type of house.

The functional house serves its occupants well because it applies scientific discoveries and principles to make it safe, convenient, clean, comfortable, economical, and attractive.

Word list for study

functional	thermostat	lath	concrete
traditional	trap	fiberboard	anneal
convection	solar house	gravity ventilation	stoker
stucco	varnish	composition	filter
kiln	plywood	shellac	

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. A functional house is one which serves the needs of the people who live in it.

B. Every step in house construction should safeguard safety and health.

C. Good absorbers of radiant energy are good radiators.

D. Poor absorbers of radiant energy are good reflectors and poor radiators.

E. When a liquid is changed to a gas, heat is absorbed, and, when a gas is changed to a liquid, heat is given off.

F. Rate of heat transference is in proportion to the difference in temperature of the radiating and receiving bodies.

G. As the temperature of the air increases the amount of water vapor required to saturate the air also increases.

H. When energy is conducted it travels from one molecule or object to another.

I. When heat travels by convection it is carried by currents in liquids or gases.

List of related ideas

1. Radiators are best painted with dark or flat paint.
2. One feels cold in a warm room when the windows are ice coated.
3. Hallways should be as small as will provide for convenient passage.
4. Some cooling systems depend upon the evaporation of water.
5. Hot air currents rise from the furnace into the living areas.
6. Stairs should have hand rails.
7. Ceilings should be white in color.
8. Heat taken in by a dark roof makes the house hot in summer.
9. The kitchen is a workshop and should be arranged in the most convenient manner.
10. As air cools in walls, insulation may become damp.
11. A dark wall absorbs more heat from the sun than does a white wall.
12. A farmhouse should be different from a city house in many ways.
13. Good light in living and working areas is essential.
14. Heating a damp house will dry it.
15. Hot water rises from the boiler to the radiator and cold water returns to the bottom of the boiler.
16. Frost may collect on a metal window sash when the walls are clear of frost.
17. No water pipe should be connected directly to any sewer pipe or connection.
18. Floors in solar houses may be moderately dark.

19. Hot water accumulates at the top of the heating tank.
20. The good house is easy to clean and to keep clean.
21. Windows should be placed with more regard for light than for decorative use.
22. Humidity of the air falls as air is heated in winter.
23. A white or aluminum roof keeps the house cooler in summer.
24. A hot stove in a cold room gives a feeling of warmth to people near it.
25. Steam radiators give off most of their heat from the condensing steam.
26. Heat travels from hot water inside the radiator to the outer surface.
27. Steam radiators may be smaller than hot-water radiators.
28. Cool basements are often damp in summer.
29. Aluminum foil is sometimes placed inside wall spaces.
30. The walls of the boiler are cooled as the water boils.
31. Most insulating material contains many air spaces.
32. Cabinets should be provided according to the kind of storage needed.
33. Good houses do not permit insects, mice, or rats to enter.
34. Heat is lost more rapidly through concrete than through an equal amount of wood.
35. It is convenient to have direct passage from the house to the garage.
36. Cold air currents tend to flow along the floor.
37. Furniture in a heated house tends to dry and shrink in winter.
38. A white shutter outside the window keeps the house cool in summer.
39. Modern houses waste little material on useless decoration.
40. Roofs may be kept cool by sprinkling them with water.

Some things to explain

1. Make a study of prefabricated houses and their advantages and disadvantages.
2. Study insulating materials, and make a report on the types which are most suitable for your locality.
3. Why does water vapor condense in walls? When? What harm is done?
4. Why are plumbers required to obtain a license before they can carry on their business?
5. Why does the cost of building a house vary so greatly over periods of several years?
6. Is the house you live in a functional house? Explain.

Some good books to read

Collins, A. F., *Simplified Household Mechanics*

Gillies, M. D., *All About Modern Decorating*

Goldstein, H. I. and Goldstein, V., *Art in Everyday Life*

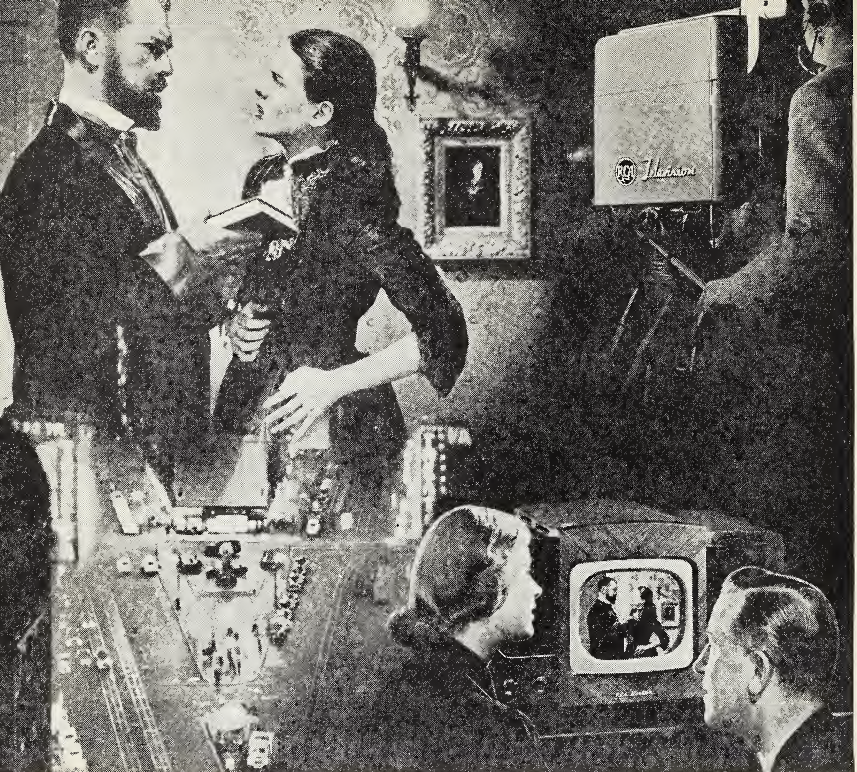
Mellish, A. J., *First Steps in Air Conditioning*

Nelson, G. and Wright, H. N., *Tomorrow's House*

New York *Herald Tribune*, Home Institute, *America's Housekeeping Book*

Post, E. P., *Personality of a House*

Robinson, E. F. and Robinson, T. P., *Your Own House*



Radio Corporation of America

UNIT FIVE

LIVING IN ONE WORLD

Ruth introduced her demonstration by saying, "While we are undertaking the large problem of understanding how transportation and communication make it possible for all people to live together in one world, I am going to demonstrate something much simpler. My experiment deals with making sounds of different pitch."

She placed a box on the table, and quickly arranged eight bottles in a row on the box. Four of the bottles were small pop bottles, and four were larger. Each bottle contained some colored water. Ruth bent over a tall bottle and sharply blew her breath across its open mouth. There was a musical, low-pitched sound. She then blew across the mouth of a smaller bottle, and produced a higher-pitched sound.

Ruth explained, "The sounds you heard were produced by the air vibrating inside the bottles. You notice that the water rises to different heights in the bottles. The longer columns of air vibrate at a slower rate than do the shorter columns of air. I use water to regulate the length of the air columns in the bottles."

She then blew upon each of the bottles in order, and the class was surprised to hear the major chord.

"It took considerable time to tune these bottles," said Ruth. "I tried some that would not produce good tones. When I did find some that sounded clear, I had to experiment by adding water or pouring it out until each bottle produced the right note. The reason that they are tuned is that the air columns vibrate according to a certain mathematical proportion. But I had no way of measuring that. I had to tune them by ear—that is, just by listening till they sounded right."

She then turned her attention to the bottles again, and blew in quick succession across the necks of several bottles. The class was amused and delighted to hear the opening notes of "America."

CHAPTER

9

Modern Methods of Transportation

People today take for granted their ability to travel rapidly and comfortably. No place in the United States is more than a few hours by air from where you live, and no place in the world is more than a few days away from your front door. Of course if you wish to reach some remote places you will have to drop from the plane by parachute, for landing fields are not available at all places you might consider visiting. If you should drop into a remote jungle or mountainous region, your travels would then be limited by your own ability to walk.

Even if you travel by automobile, you can cross the United States in about 10 days by traveling at safe speeds. This rate of travel is in itself marvelous. As you travel about the United States you will find less difference between cities than you might desire. The same chain stores, the same street traffic signs, and the same pop stands seem to be everywhere. Transportation has helped to make the United States one country.

To a lesser degree transportation is now making most of the countries of the world into one world. Every country in the world is our neighbor, and because this is becoming increasingly true, it is increasingly important that we learn how to live with our neighbors and understand them.

Some activities to do

1. Make model automobiles and airplanes with jet propulsion. The carbon dioxide cartridges used to charge soda water will furnish the power. You can find directions in books on model making. The planes can be controlled by hanging them from tightly stretched wires.

2. The latitude of a place is the same as the altitude of the North Star above the horizon expressed in degrees. You will need two straight lines to determine the angle. One is a horizontal line; the other is a line pointing to the North Star. Work out a way of

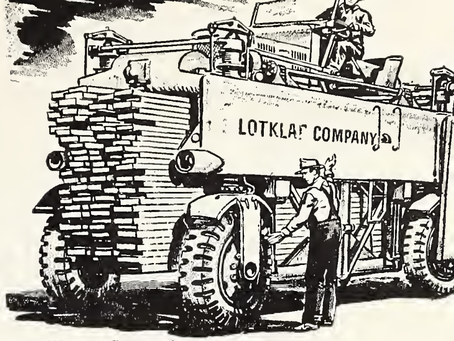
finding these two lines and measuring the angle they make. Compare your results with the latitude of your city as expressed on a map of your state.

3. Make a survey of the various kinds of transportation in your community. If the community is large, divide the class into committees, each reporting on one phase of transportation. Arrange to visit railroad terminals, wharves, express depots, airports, and bus stations.

4. Divide the class into committees to make a traffic survey. Count the number of automobiles passing a given point on various highways at different times of day. Observe and report traffic-law violations by drivers and pedestrians. Locate danger points where accidents are most likely to occur. Report on the use of signs and billboards which take the driver's attention from the road. Check the distance of visibility at intersections and curves. Check placing of signs and signals to discover if they are located where needed. Send a report of your survey to the official in charge of traffic in your city or community.

5. You can check speed by making two marks on the roadside 176 feet apart. A car traveling 30 miles per hour passes through this distance in 4 seconds. You can calculate other speeds similarly. Use a stop watch. (*Keep off the street!*)

6. Develop a traffic safety campaign suited to the needs of your school and community.



Borg-Warner Corporation

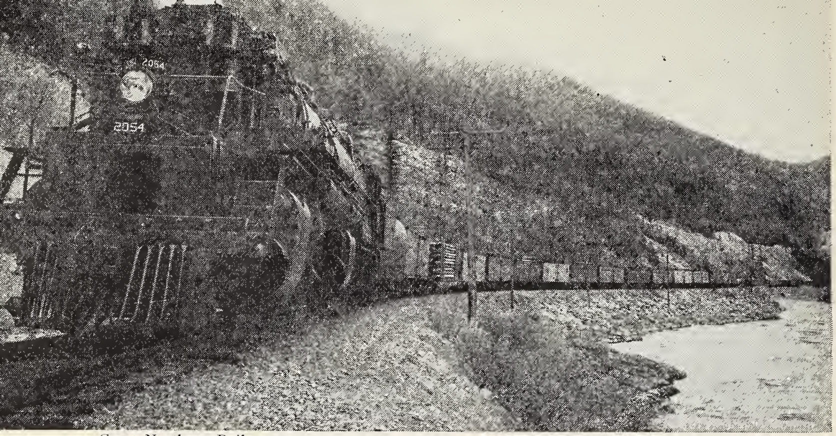
The "straddle truck," its wheels on stilt-like legs, rolls into position above the load, lifts as much as 15 tons at a time, and rolls away with it to a new place. What special jobs would best be done by such a truck?

Some subjects for reports

1. Rocket trips to outer space
2. Traffic laws in your town
3. The automobile parking problem
4. Automobile driving tests and licensing
5. New model automobiles
6. The fastest travel by trains on record
7. Freight trains and special kinds of freight cars
8. How a submarine works
9. Archimedes experiments with weight of objects in water
10. Newton's discoveries of the laws of motion

1. *What resistances must transportation overcome?*

All the types of machines, such as streetcars, buses, airplanes, trucks, and trains, which are used in transportation encounter cer-



Great Northern Railway

This heavy freight train must overcome considerable inertia to start or stop. Even on slight grades in mountains, gravity must be overcome.

tain forces which resist their motion. These familiar forces are gravity, friction, inertia, and air resistance. Every transportation device must be designed to overcome these forces, and in addition must offer convenience, comfort, safety, and economy of operation.

How does friction resist motion? All machines used in transportation have moving parts, and wherever parts move against each other there is friction. The wheel was probably the first device used in overcoming friction. The problem of attaching a wheel to an axle must have been difficult for primitive man to solve.

Friction is decreased by smoothing the surfaces which move against each other. The polished surfaces of streamliners and the shining bodies of airplanes contribute to overcoming friction. Inside the machines, bearings of smooth metal have replaced the rougher surfaces used in earlier machines.

Ball bearings and roller bearings are used to provide rolling instead of sliding friction. New types of lubricants, made of oils, soaps, metals in suspension, and other chemicals reduce friction. We have spent billions of dollars in building smooth roads. It would cost more than 20 billion dollars to replace the roads now in use, exclusive of city streets.

How does gravity resist motion? Gravity offers resistance to all uphill movement or movement away from the surface of the earth. The airplane not only must overcome air resistance but must constantly maintain its own weight against the pull of gravity. Every object not supported falls with an acceleration, or pickup, of 32 feet per second. That is, if an airplane failed to support itself but fell like a rock,


U. S. Bureau of Public Roads

To overcome inertia, a curved road is banked. The motion in a straight line is changed into motion around the curve in part by the force of gravity and in part by friction. What would happen if the driver should fail to make the turn?

it would be dropping at a speed of 32 feet per second at the end of a second.

When a road passes over a hill, the load and vehicle must be lifted against gravity to a distance equal to the height of the hill. Even small bumps in the road make it necessary to overcome gravity. A heavily loaded truck, in passing over a series of bumps, uses enough energy to lift the truck to the total height of the bumps. The jolting of the vehicle and its load as it drops off the bump wears out the machine more rapidly than occurs on smooth roads. It is estimated that smooth concrete roads permit operation of trucks for about 60 per cent of the cost of trucking on rough gravel roads.

How does inertia resist motion? Inertia is the tendency of an object at rest to remain at rest or of an object in motion to remain in motion in the same straight line. When you start an automobile, energy must be supplied until the inertia of standing still is overcome. The energy then is stored in the moving automobile as kinetic energy. When you are required to stop, the kinetic energy is changed to heat by the brakes and friction of the parts of the automobile.

Any increase in speed is called acceleration. The rate of acceleration, or pickup, is in proportion to the force used. Because in city traffic it is necessary to overcome inertia quickly, it is desirable to have powerful, expensive engines in automobiles. One can obtain 15 to 25 miles per gallon of gas on the highway but only 10 to 15 miles per gallon in the city.

Trains traveling at high speeds and weighing many times more than an automobile, have much kinetic energy. Because large amounts of energy are lost every time a train stops, train schedules

are arranged to require few stops. Lightweight trains are replacing heavy trains for local traffic.

Inertia of the air makes it possible for airplanes to fly. The air resists motion for an instant, which provides the resistance necessary for the wings and propeller to act against.

The inertia of a body in motion is in proportion to its weight and to the square of its speed.

The common pendulum shows very well the problems of acceleration, gravity, and inertia. When you support a weight by a cord, the weight stands still. When you put a certain amount of energy in the weight, it swings upward and overcomes gravity until the energy is stored. Then it swings downward, increasing in speed until it reaches the lowest point the string will reach. Gradually, on the upswing the speed decreases, and the weight stops and swings back through its former positions in reverse order.

Because inertia causes objects to travel in straight lines, we try to make our curving roads turn gradually. Not only is a straight line the shortest distance between two points, but it is also the safest. Any vehicle resists being turned with a certain amount of force, which increases with the square of the speed. Roads are banked to absorb some of this kinetic energy and change it to friction.

How does air resist motion? One of the most important of the forces retarding motion at high speeds is the resistance of the air. Below the speed of sound air resistance increases with about the square of the speed. That is, at 100 miles an hour, air resistance is 10,000 times that at one mile an hour.

Two factors determine air resistance. One is the difference in pressure behind and in front of an object. The other is friction.

If an object is so shaped that a partial vacuum forms behind it, air pressure tends to push that object backward. A boxcar is the standard example of such an object. The forward movement increases the air pressure against the front end of the car, and the eddies reduce the pressure at the rear.

To make the air flow more smoothly past a vehicle, it is streamlined. An egg or a fish has a streamlined shape. The large end of the egg-shaped vehicle is the front. Around such an object, air flows smoothly and meets in a single stream at the rear. Projections set up eddies which increase friction along the sides of the object and create differences of air pressure.

Because of its shape, a fish can keep its head upstream and with very little effort hold its position against a current.

DEMONSTRATION: WHAT FORCES RESIST TRANSPORTATION?

What to use: Wooden darning egg, slender nail, small toy automobile

filled with paraffin, coin, card, tumbler, string, weight, support.

What to do: Drive the nail into the darning egg. Hold the egg under the faucet, with the large end up. Turn the water on. Note the smooth flow of water around the egg. Next hold the toy automobile under the stream of water. Observe the uneven flow of water. Try each under a much more rapid stream of water.

Place a coin on a card over the open mouth of the tumbler. With the finger, snap the card off the tumbler.

Make a pendulum by tying a weight to a support with a string. Start it swinging. Observe changes in speed. Change the length of the string, and observe the change in the rate of the pendulum.

What was observed: Describe or draw a diagram of the flow of water around the egg and the toy automobile. Why does the coin fall in the glass? State the effect of length of cord upon the pendulum.

What was learned: In terms of the demonstration, explain the following words: streamlining, inertia, gravity, acceleration.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: FRICTION, GRAVITY, INERTIA, AIR RESISTANCE. *Below are devices or methods used in transportation to overcome one or more of the above listed resistances. Write these words in the column where they fit best:* smooth surfaces, smooth roads, level roads, egg shape, wheels, pull of propeller, ball bearing, no projections, oil, brakes, straight roads, few stops, lightweight, roller bearings, few grades, polished body surfaces, accelerators.

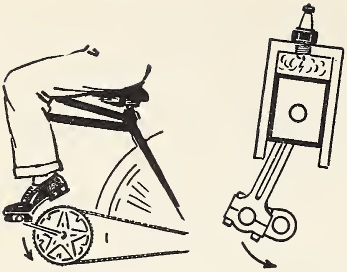
2. How is the automobile operated?

Since its first development in the years before 1900 the automobile has constantly been made faster, more powerful, and more complex. Changes are still being made. Some of these changes make the automobile still more complex, more expensive, and less efficient in getting mileage from gasoline. But they generally do increase ease of driving and comfort of riding.

What moves the automobile? The standard automobile has a four-cycle gasoline engine to provide power.

The force of the exploding gasoline thrusts the piston downward. The piston is really the enlarged end of a lever called the connecting rod. The connecting rod carries the thrust down to the crankshaft. The cranks of a crankshaft operate exactly like the cranks of your bicycle. You ride by causing your feet to exert a downward thrust upon the cranks in turn. The automobile has pistons and connecting rods, instead of feet, and four to twelve cranks on the same rod, instead of only two.

At the rear of the engine the crankshaft is connected to the flywheel. A shaft connects the flywheel to the clutch.



Your foot applies force to a bicycle crank much as the piston connecting rod applies force to the automobile crankshaft.

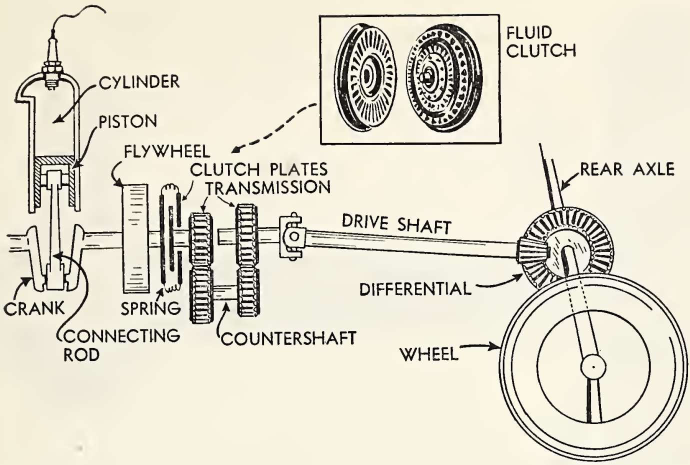
What is the clutch? It is necessary to disconnect the engine from the automobile to start it. The electric starter motor provides energy to move the pistons up and down, pumping fuel into the cylinders in turn and causing the spark to ignite it. Usually several seconds elapse before the correct proportions of air and gasoline are present in the cylinder to cause the engine to start under its own power. When the engine is started, it is necessary to apply the force gradually to overcome the inertia of the automobile. The clutch applies power gradually and permits starting the car smoothly.

The standard clutch is made of three plates. The first and third are connected to the crankshaft. These two are held against the middle plate by springs, and they all turn because of friction. The middle plate is attached to a steel shaft which carries power toward the wheels. When you press down on the clutch pedal, you release the pressure of the springs. The plates slip and do not turn the shaft connected to the wheels. When you gradually let the pedal up, the friction increases; and there is less and less slipping, until the force gradually applied moves the automobile smoothly forward. In many cars the clutch is controlled by automatic devices, and the driver has no direct control over it.

Some cars have a hydraulic or fluid coupling. It consists of two or more paddle wheels enclosed in a container filled with oil. The first paddle wheel is turned by the engine and causes the oil to whirl. The second is connected to the drive shaft and is turned by the oil whirled around by the first paddle wheel. The oil slips when the engine is turning slowly but applies its force efficiently to the driven paddle wheel when the speed of the engine increases. This coupling may be placed in front of the clutch, or may replace it.

What is the transmission? You know that one of the operations of learning to drive many automobiles is the shifting of gears. These gears, taken together, make up the transmission. The transmission lies just behind the clutch.

The advantage of gears is that they produce changes in direction of force and in mechanical advantage. The mechanical advantage of gears is easily calculated. You count the number of teeth on each gear. If the driven gear has twenty-four teeth and the driving gear has eight teeth,



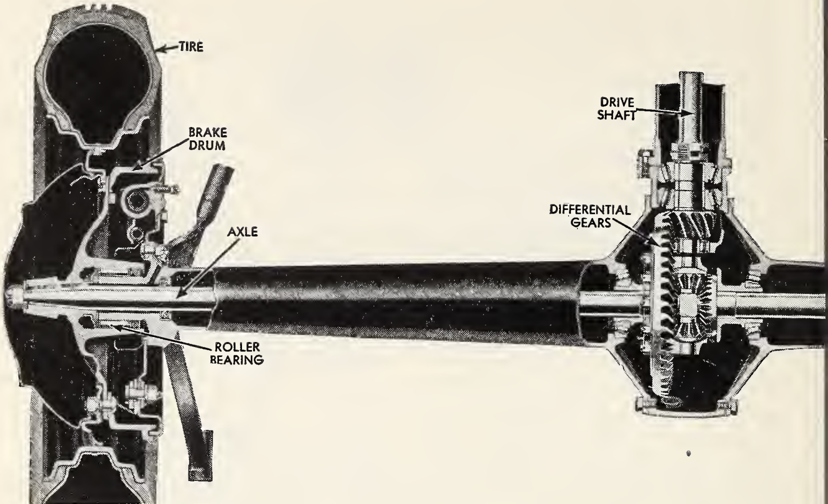
This diagram shows the parts of the automobile which carry force from the cylinder to the rear tire. The standard clutch is shown in the large drawing. The fluid clutch shown in the inset may be added to the transmission. The gear shift is in intermediate.

the mechanical advantage of the gears is three—that is, the force is multiplied three times, and the speed is reduced to one-third of what it was. By having the larger gear for the driving gear, the speed is increased, and the mechanical advantage becomes less than one.

The transmission is made up of spur gears. In automobiles the teeth of the gears are curved so that they will slide together easily. There are two shafts in the standard transmission. One shaft goes directly through the transmission and on to the wheels. This shaft may carry power directly from the engine to the wheels when the car is in high gear. This shaft is out-of-gear for low, intermediate, and reverse gears. The second shaft, called a countershaft, is below the first and has a number of gear wheels on it. The gears on this countershaft may be moved back and forth by the shift levers. Various combinations of gears carry the power to the wheels.

When the shift is in low, a small gear is connected to a large gear, increasing the power. The automobile is started in low. To increase the speed, the gears are shifted into second. When shifting gears, the clutch pedal is pushed downward or operated automatically to disconnect the engine from the gears. Automobiles are now so made that part or all of the work of shifting gears is done automatically.

How is force applied to the ground? The rod which carries force from the gears to the



Ford Motor Company

The differential gears transmit power from the drive shaft to the rear wheel.

wheels is called a drive shaft. It has in it a joint or hinge which prevents the bouncing of the rear wheels from shaking the transmission apart. The direction of the force must turn at right angles in passing from the drive shaft to the rear axles. To make this turn possible, a bevel or worm gear is used. The driving gear is much smaller than the driven gear. When the automobile is traveling straight ahead, the rear axle turns as a single rod, with the wheels attached at either end.

When the automobile comes to a curve, the outer wheel turns faster than the inner wheel. The rear axle then separates into two parts. In the middle of the axle is a set of four to six bevel gears, called the differential, so arranged that the power is always carried to the wheel having the smaller amount of resistance to overcome. When the resistance to the wheels is equal, they turn at equal speeds.

The differential prevents dragging of the wheels and uneven wear on tires, and it makes easy turning possible.

The rear wheels are the final step in carrying power from the engine to the ground. The wheel not only provides rolling friction, but its spokes act as levers which push the automobile along. It is essential that the rear wheels grip the road firmly.

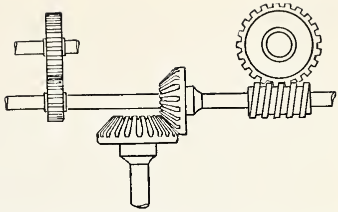
Some automobiles have the engine in the rear. They have the same essential parts as others, but they are arranged somewhat differently. A few cars have the driving power applied to the front wheels, or to all four wheels.

Below and behind the crankshaft pulley is a set of spur gears. These gears may be attached directly or connected with a gear chain. These gears turn a shaft which opens and closes the valves exactly at the right time to admit fuel and to let out the exhaust gases. They also control the time at which the spark jumps the gap in the spark plug.

On the flywheel are gear teeth which are engaged by the gears of the starting motor. The starting motor is an ordinary electric motor operated by current from the storage battery. The starter gears are not connected with the flywheel except in starting the automobile.

What are the other systems driven by the engine? At the front of the engine is a belt passing over three pulleys. The bottom pulley wheel may be attached to the crankshaft, the top pulley to the fan, and the one to the side to the water pump. This pump circulates water from the radiator.

The generator is used to charge the storage battery and to supply current to the electrical system of the automobile. The generator is frequently placed directly behind the fan in order that the heat produced by current flowing through its coils will be carried away without harm to the wiring. The generator produces direct current. It is connected to an ammeter at the instrument board, where the driver can see whether the battery is being charged or discharged.



There are several types of gears. Three of the most common are shown in this diagram. They are, in order, spur, bevel, and worm gears. These various gears are used to carry power in the automobile.

DEMONSTRATION: HOW DO GEARS OPERATE?

What to use: Gears—demonstration, automobile, or clock.

What to do: Count the teeth on the gears. Connect and operate them.

What was observed: Describe the appearance of the gears. How many teeth are on each gear wheel? Which turns faster, the large or small gears?

What was learned: State how the mechanical advantage of gears is calculated.

Exercise

Redraw and label the diagram on page 425 showing the relation of the parts of the automobile to each other. Reverse the drawing—that is, have the cylinder on the right. Make your drawing twice the size of the one in the book. Add as many parts to the drawing as you can. Also complete these sentences:

Power from gasoline is applied to the —1—. The connecting rod carries it to the —2—. The —3— changes its direction and carries it to the —4—. The —5— applies it to the axle.

3. How is the automobile constructed?

The first automobiles were merely horse-drawn buggies with gasoline engines substituted for the horses. Some even had sockets for buggy whips. Many years of improvement and work have resulted in the automobile of today—powerful, fast, and comfortable. Not the least of the improvement of the automobile has been in construction of the body.

How is the body made? Automobiles of today are all built on a modified streamlined plan. That is, surfaces slope at an angle instead of being straight up and down, and corners are rounded. Door handles are sunk into the body, headlamps are molded into the body, and fenders are smoothed and rounded in shape. The automobile frame was once separate from the body, but the tendency today is to make an all-steel body with the frame and body in one piece.

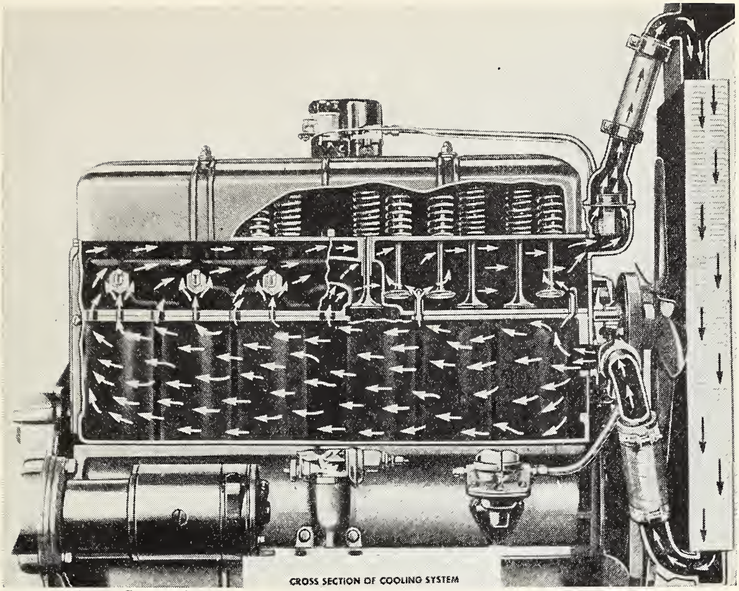
The importance of streamlining is perhaps slightly overestimated. At speeds above 40 miles an hour air resistance becomes an important factor in economy of operation. Even at 40 miles an hour, more than half the effective energy is used to overcome air resistance. It is probable that the trend toward streamlining will continue.

The ventilation of the automobile is highly important from a safety angle. Carbon monoxide gas frequently leaks into the riding space and causes sleepiness or loss of attention. Many accidents are caused by poor ventilation. Most automobiles of today are ventilated by air from a wing-window combination. Air is directed through the riding zone without causing uncomfortable drafts.

By changing the engine to the rear, it is possible to make an automobile more completely streamlined than with the engine in front. But such a change makes it necessary to change the distribution of weight of the rest of the automobile in order to keep it in balance.

In order to make an automobile still safer it should have crash padding on the instrument panels, much better bumpers all-around the body which would absorb some of the shock of collision, and for better visibility a larger windshield, larger windows and rear vision mirror, and a lower and more rounded hood.

How are the lights constructed? The automobile lighting system is a direct-current, 6-volt system. The lamps use a large number of amperes, compared with house lights, to produce a given wattage, and consequently provide bright light. Automobile lamps are more rugged than house lamps. Reflectors are used to direct the beam to the road. Lamps and reflectors are built as a unit, part of the reflector being in the bulb itself. They throw the light upon the road and not into the approaching driver's eyes.



General Motors Corporation

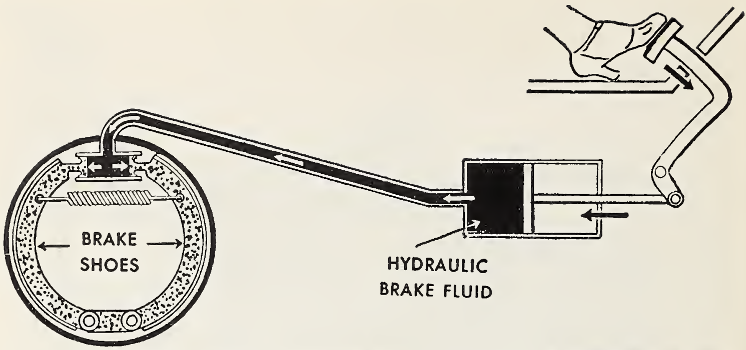
This is a cross section of the cooling system of a six-cylinder engine.

No automobile has lights good enough to justify driving at night at speeds higher than 40 miles an hour on ordinary dark highways or 25 miles an hour in city traffic.

How does the cooling system work? Because the burning temperature of gasoline is high, the engine, if uncooled, would soon become so hot that it would burn the lubricating oil, and the metal would expand until the parts would no longer move. To cool the engine, water is circulated through spaces in the metal block in which the cylinders are bored.

Water is stored in the radiator. The radiator and engine are connected by pumps and pieces of hose. Water heated by the engine has a natural tendency to circulate by convection. To increase the circulation of water, a centrifugal or rotary pump is driven by a belt from the crankshaft. The water cools in the radiator, falls, passes through the engine and is heated, rises, and is pumped back to the radiator. The fan causes a current of air to cool the radiator. The radiator tubes are connected by metal fins which conduct heat rapidly into the air.

How do the brakes work? There is one brake on each wheel. The brake consists of a metal drum which looks much like a straight-sided saucepan. It is attached to the wheel. Inside the drum is a circular band,



Can you trace the application of force from the foot to the wheel of the automobile by studying this diagram of a hydraulic brake system?

called the shoe, which barely clears the sides of the drum. When pressure is applied to the brake pedal, the shoes are pressed forcibly against the inside of the drums and produce friction to stop the movement of the wheels.

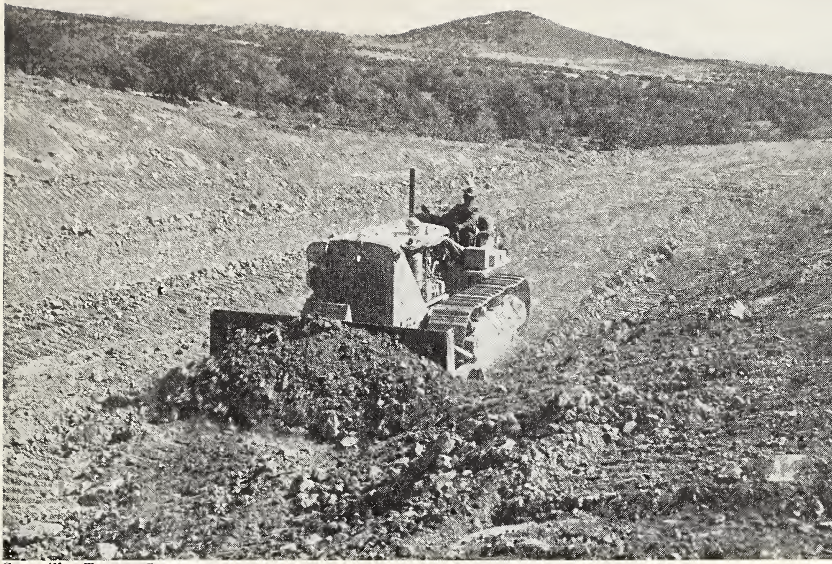
The shoes are covered with asbestos, interwoven with copper wire, which resists heating, is strong, grips well, and is quite durable. It is occasionally necessary to have this asbestos lining replaced.

Most automobiles have hydraulic brakes. A cylinder or tank of liquid underneath the body is connected to the various brakes. Each wheel brake contains a cylinder and a pair of pistons. When the brake pedal is pressed, a pump forces liquid under pressure from the cylinder or tank to the brake cylinders. The brake pistons press the shoes against the drums.

How is gasoline supplied to the engine? A tube runs from the gasoline tank to a force pump which pumps the gasoline into the carburetor. In the carburetor the gasoline is mixed with air, and the mixture goes through the intake pipes to the engine. The intake pipe is heated by passing along the engine and past the hot exhaust. The use of heat increases the vaporization of the gasoline.

When a fuel vaporizes slowly, the engine does not have pickup. If fuel burns too rapidly it causes a knock. Materials are added to gasoline to make it burn evenly and decrease the tendency to knock. The measure of knock is called the octane rating.

What happens to the energy of gasoline? It is estimated that, under good conditions, only about 7 per cent of the energy of gasoline ever reaches the wheels to propel the automobile forward. The remaining 93 per cent is wasted in heating water, in exhaust gases, and in friction, in the order named. Some energy is used for the storage battery and the devices which operate the engine.



Caterpillar Tractor Company

The first step in building a road is the preparation of a roadbed. Many kinds of machines are used for this purpose.

Because it is impossible to heat water above the boiling point—212 degrees Fahrenheit—and because the rate of movement of heat is in proportion to the differences in temperature, the heat losses with a water-cooled engine cannot be avoided.

The exhaust gases waste energy in two ways. Heat is lost in the burned gases. A second exhaust loss is through the escape of unburned gasoline and carbon monoxide. Both these materials contain unused energy.

Loss of energy from friction is only slightly less than the losses through water and exhaust heat. Every cylinder, every bearing, every gear, and every moving surface encounters friction. Friction is reduced by use of lubricating oils. The bearings of the crankshaft operate in a bath of oil, and oil is forced by an oil pump through tubes in the engine parts to points where friction is greatest. Grease is used on the bearings of the wheels and in the transmission and differential.

The so-called useful energy—that delivered on the road—is used to overcome road friction, to overcome gravity in going uphill, and in overcoming air resistance. Eventually all this energy is lost.

DEMONSTRATION:
WHAT IS THE PRINCIPLE OF THE BRAKE?

What to use: Small electric motor, spring clothespin.

What to do: Set up the motor so that it runs strongly and smoothly. Pinch the clothespin to open it wide, and place it around the revolving shaft. Gradually permit the clothespin to close, and note the effect on the motor. Feel the shaft.

What was observed: Can a motor be stopped by use of a brake?

What was learned: What happens to the energy removed by a brake?

Exercise

Write a paragraph summarizing this problem, using in it the following words: radiator, fan, belt, pump, friction, exhaust, heating water, power, efficiency, chassis, brake, streamlining, 93 per cent, 7 per cent.

4. How are safe highways constructed?

To make travel safe and economical, it is just as important to have good roads as it is to have good automobiles. The problems of road building are to locate the road correctly, to construct it of durable and suitable materials, to develop the road in relation to the surroundings, to provide for city traffic, and to make certain that the road will be used safely. The highways of the United States are not adequate to handle present traffic safely.

How is the location of the road determined? The road must be placed where the people need it most. Farm roads run to near-by towns. Highways connect towns and cities. Superhighways connect one population center with another.

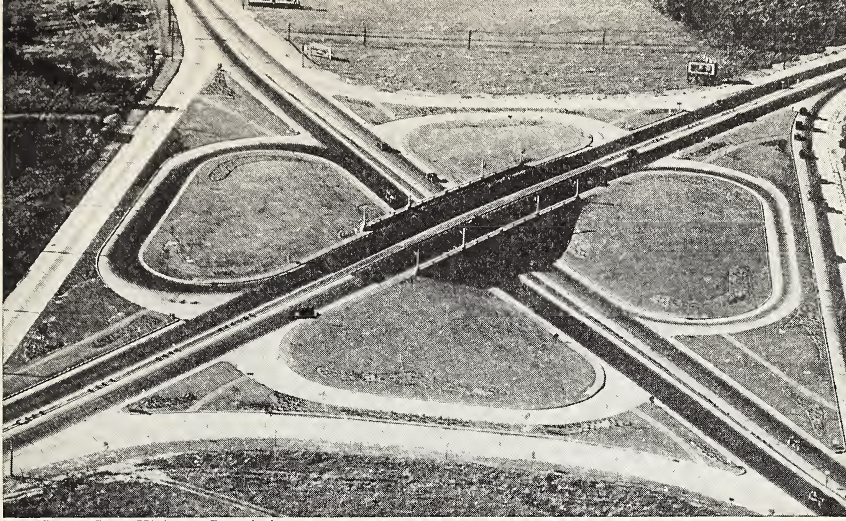
The road must be as straight and level as possible. The U, or hairpin, turn is dangerous, for people often drive off the road because of centrifugal force. Yet no grade should exceed 9 per cent, and few grades should exceed 5 per cent. The grade is measured in the number of feet of rise in 100 feet of distance.

Traffic lanes must be separated to avoid collisions. The three-lane road is one of man's deadliest inventions, for the center lane is the scene of head-on collisions. Modern roads are made with four lanes, with opposing traffic separated by a grassy strip. Cross traffic must also be separated or controlled. The cloverleaf intersection is made with one road passing above the other and with turnoffs provided to prevent left-hand turns.

Railroad grade crossings are another danger point. Overpasses or underpasses are the only satisfactory solution for this problem.

The road should provide visibility for a distance of 600 feet. Crossroads, side roads, pedestrian crossings, and roadside stands should be visible for this distance. No curve should be blind, unless completely protected by signals.

How are good roads constructed? The first problem of making a road is to provide a solid roadbed. This is done by moving soil and rock from cuts to fills or, in level places, by pack-



New Jersey State Highway Commission

The clover-leaf intersection is the safest crossing so far developed. Its cost makes it practical only where traffic is heavy. Study this picture and tell how automobiles get from one highway to the other without making any left turns.

ing the soil firmly by use of machines. The roadbed is often filled with rock. Ample drainage is a necessity and is provided by use of ditches, tiles, and concrete spillways.

The half-million miles of roads in the United States are about equally divided among three types of surfaces, concrete, asphalt, and untreated surfaces.

Concrete is poured on a stone base and usually reinforced with steel bars or with steel netting. Quick-hardening concrete has been developed to speed up road building. Black-top roads may be made by treating gravel with asphalt or oil and spreading the mixture on the road, or by pouring the oil on the road and mixing it with the gravel. The mixing is done with scrapers. Heavy rollers then smooth the surface of black-top roads. Untreated roads are made by plowing, scraping, and hauling earth and stone.

Concrete roads are most expensive to build, black-top roads next, and untreated roads are least expensive.

Bridges are an important part of good roads. Short bridges are generally of the concrete-arch or steel-girder type. Longer bridges are often made of high concrete arches. These bridges require solid support on the river or valley bed. Steel girders may be substituted for concrete but still must rest upon pillars for support. The suspension bridge is supported only at the ends, the support being two huge steel cables. The bridge is suspended on other cables below these. Suspension

Bureau of New Orleans "News"

This bridge, almost five miles long, carries railroad and automobile traffic across the Mississippi River.

bridges must be carefully constructed to avoid being swayed by the wind. One such bridge has been caused to collapse by wind. In a few places tunnels have been found to be safer and better than bridges.

What is good roadside development? The roadside should be developed to aid, not obstruct, the safe movement of traffic. Superhighways are made with clear land for 100 feet or more on each side of the road, gently sloped to prevent a car rolling over if it leaves the road. There are no billboards along such roads nor are there any roadside stands or crossings. The right of way is securely fenced on both sides. Places are provided for turning off to rest or to change tires.

The average roadside is so cluttered with intersecting roads, billboards, stray cattle, pedestrians, farm wagons, filling stations, hamburger stands, and a variety of other means of distracting attention, that it is not amazing that many automobile accidents occur because the driver's attention is distracted from the road.

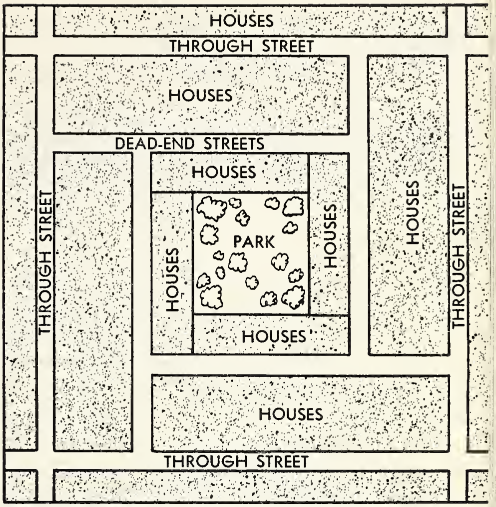
What are good city streets? Streets, for proper use, must be classified to serve definite purposes. Some streets should be declared through-traffic streets and guarded with every possible safety device—overpasses or underpasses, fences, and signals. On these streets there should be no streetcars, filling stations, parking, or cross walks. All other streets should be low-speed streets, restricted to speeds of 25 miles an hour or less and controlled by traffic-light signals as needed. In residential districts

it is advisable where possible to change street plans to provide for dead-end streets to discourage speeding. It is essential to provide playgrounds to remove playing children from the street.

Parking is a problem which no city has solved. The only solution is to provide, when money is available, for off-the-street parking, either inside buildings or on parking lots. Cities are spreading over larger areas because parking is too much of a problem in central districts.

What are the three E's? Traffic engineers say that the three E's of safety are Engineering, Enforcement, and Education. Many traffic accidents may be prevented by building safe roads. Many so-called accidents are not accidents but the result of willful, criminal disobedience of the law. The only way to curb the criminal driver is to keep him from driving. Many so-called good citizens obey all laws but traffic laws.

Education is the need of most drivers. They do not know danger spots. They are careless in giving and observing signals, and too often drive carelessly or recklessly.



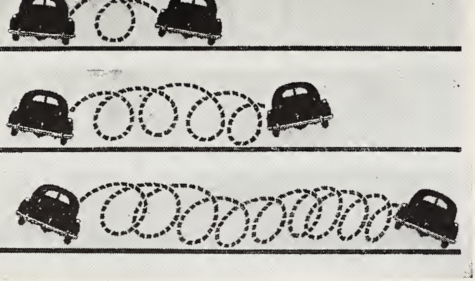
This diagram shows the plan of a large city block, one-half mile on each side. It is bounded by through streets. Within the block are dead-end streets and a park playground.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: RURAL ROADS, HIGHWAYS, SUPERHIGHWAYS, CITY STREETS. *In the correct column or columns write the following means of increasing traffic safety*: no roadside stands, traffic lights, clear visibility for 600 feet, no railroad grade crossings, no billboards, straight roads, dead-end pattern, clover-leaf intersections, grades of 5 per cent or less, no parking, strict regulation of speed, footpaths, no curves, four-lane bridges.

5. Do you want to drive?

If you want to have the privilege of driving an automobile, you must do your share to improve the traffic safety record of young drivers. Young drivers are involved in so many more accidents, and in more serious accidents, than older drivers that it is becoming increasingly difficult for them to obtain and keep



Traveler's Insurance Company

The force with which you roll over in an automobile accident is in proportion to the square of the speed. The automobiles are traveling 25, 50, and 75 miles an hour. Each loop represents rolling over once.

driver licenses in many states. Insurance companies are generally reluctant to insure cars driven by drivers younger than 22 to 25 years of age.

Safe driving depends chiefly upon two things, skill in operation of the car, and a mental attitude of putting safety above everything else. Instead of putting safety first, many young drivers place it after speed, showing off, and disregard for the rights of others.

Are automobiles really dangerous? Look around you, and select 100 people you know—neighbors, schoolmates, and your own family. Within a year one of them will be injured in an automobile accident in an average group.

In the United States between 30,000 and 40,000 people are killed every year, and more than 1,200,000 are injured.

Even if you do not drive, you are not safe; for more than 40 per cent of those killed and 25 per cent of those injured are pedestrians.

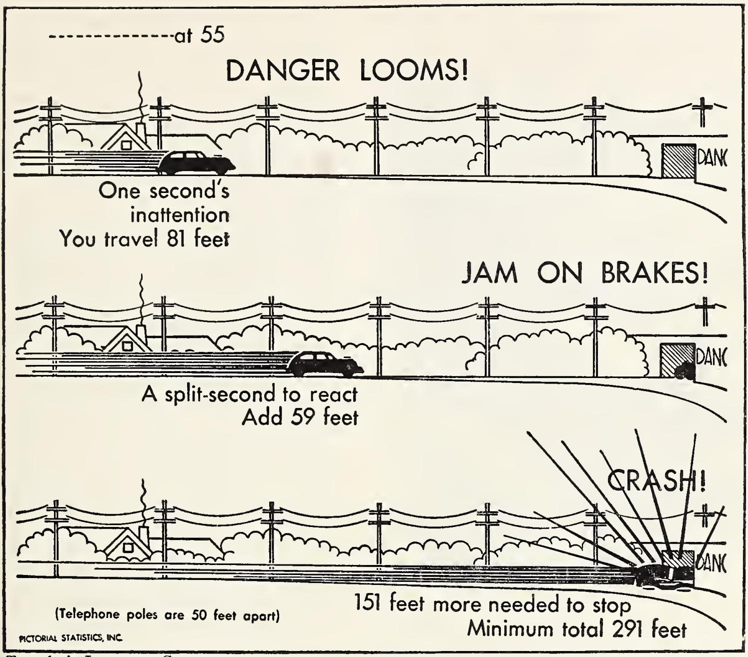
Does speed make a difference? Rolling along at 25 miles an hour seems tame. At 50 miles an hour you may still feel that the world moves by slowly. When you are rolling along at 75, you may feel a thrill of pleasure and excitement.

But instead of thinking of rolling *along,* think of rolling *over.*

It takes only a little accident to start an automobile rolling over. At 25 miles an hour, you have about enough energy to roll over once. If your automobile has a steel top, safety glass, and if you are fortunate, you may come out of the accident with minor injuries. At 50 miles an hour, you will roll over, not twice, but *four* times. Accidents of this sort are serious—people are fortunate to come out alive. At 75 miles, you will roll over, not three times, but *nine,* provided the automobile did not strike a tree or other solid object. People rarely survive such accidents.

A collision at 60 miles an hour delivers almost as much shock as a fall from a 12-story building. Would you step carelessly from a 12th-story window?

In going around curves, the same principle holds true. You can make almost any turn you are likely to find in a road at 25 miles an hour. At 50 miles an hour, you can turn only one-fourth as rapidly. And at 75 miles an hour, you can turn only one-ninth as rapidly as at 25 miles an



Traveler's Insurance Company

"You bet your life" when you drive at high speeds.

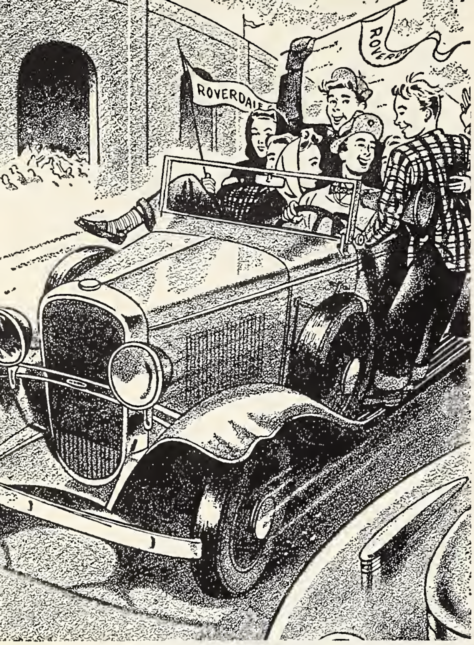
hour. Cutting in, passing, and turning ordinary curves becomes a highly dangerous gamble at high speeds.

This law is a law of physics and will never be repealed. No judge can let the driver off lightly for violating it. No matter who you are or how well you can drive, *the striking force of your automobile increases in proportion to the square of its speed.*

Can people drive at high speeds with safety? There is one part of the driving mechanism of the automobile that can't be made safe—the driver. The old 1915 model driver will sit at the wheel of the 1960 model automobile.

The human nervous system reacts slowly. It takes the average person more than half a second to see a situation and to act in any way. Even if the driver is fully alert, he cannot normally put the brakes on in this short a time. In 3/4 of a second, at 40 miles an hour, the automobile travels 44 feet. For this distance the automobile is absolutely out of control—driverless as far as any power to act is concerned.

When the driver finally reacts, the distance the car travels before it is stopped depends upon the



Traveler's Insurance Company

When you see a jalopy overloaded with overexcited high school pupils can you also see danger? Write your own explanation of this picture.

square of the speed. Even at 40 miles an hour, more than 100 feet are required for the brakes to stop an automobile under favorable conditions. At 55 miles an hour, more than 150 feet are required. A tire on dry concrete has about 11 times the grip that it has on ice.

What conditions produce accidents? There are some special conditions which make accidents more likely to occur. The young driver—the age group from 16 to 20—has about twice as many accidents and five times as many fatal accidents as the average for all other drivers. Driving at night is particularly dangerous. Three-fifths of the fatal accidents occur at night. Under good conditions a driver can see only about 100 feet at night, but it requires 172 feet under average conditions to stop at 50 miles per hour.

The commonest accidents include a car striking a pedestrian at an intersection, or on a concrete road, or a jaywalker between intersections; collisions between cars at intersections; head-on collisions at intersections or on highways; sideswiping either from driving too close to the center line or cutting in when passing; merely driving off the road because of too much speed or inattention; and striking such objects as cattle, farm wagons, and rocks on the road. All these accidents result either from driving too fast or with too little judgment.

What rules should you observe when you learn to drive? There are nine rules for drivers to observe.

1. Drive more slowly than you think is the safe speed. Observe speed laws. *Be sure* that you can stop within the distance that you can see ahead.

2. Stay on your own side of the road. No matter how safe the road seems, keep well to the right. Never pass the center line or even approach it closely on hills and curves.

3. Wait to cross until you have the right of way, and cross only at intersections.

4. Don't cut in and out of traf-

fic. Get in your lane and stay there.

5. Stop behind standing streetcars and school buses and go carefully around parked automobiles.

6. Use the signals legal in your community.

7. Drive so cautiously that even in case of a blowout or other accident you could stay on the road. Never show off. Keep your mind on driving.

8. Do not go on the road until you can perform every operation of driving an automobile five times in succession without an error, with a competent teacher checking your driving.

9. Do not drive for more than three hours without resting. Do not drive more than five hours in one day. Fatigue is a major cause of fatal accidents.

DEMONSTRATION: WHAT IS YOUR REACTION TIME?

What to use: Coin, ruler.

What to do: Stand about two feet away from your subject, who should stand with his feet together facing you. Hold the coin loosely between your thumb and forefinger 30 inches above the floor. Have the subject watch the coin. Then, without warning, drop it, and let him try to thrust his right foot under the coin. Try this five times.

If the subject fails three times in five, drop the coin from a height of 48 inches, and repeat. If he still fails, drop the coin from a height of 70 inches. A coin falls 30 inches in 2/5 of a second, 48 inches in 1/2 of a second, and 70 inches in 3/5 of a second.

What was observed: Work this problem: With your own reaction time, through what distance would you be out of control driving a car at a speed of 45 miles an hour. At this speed, an automobile travels 66 feet a second.

What was learned: What is a safe driving speed?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: square of the speed, force, collision, one-half of a second, after dark, 40 miles an hour, reaction time, safest speed, 40,000, pass on curves and hills, signal, right of way.

6. How do we provide land transportation?

More people travel more miles, more safely and at less expense, on public transportation systems on land than by any other means. Buses, streetcars, local trains, and long distance trains provide the safest transportation. Without these means of transportation modern cities could not exist, for there is not room on streets for enough automobiles to convey people for shopping, work, and general travel. Railroads do more long-distance freight hauling than all other systems together.

What problems must railroads solve? Safety of trains depends largely upon good tracks. Railroads are built with few curves and the grades are slight. Heavy

New York Central System

This fully streamlined steam train was running at 70 miles per hour when this picture was taken. Note the drive wheels of the locomotive and the smooth connections between cars.

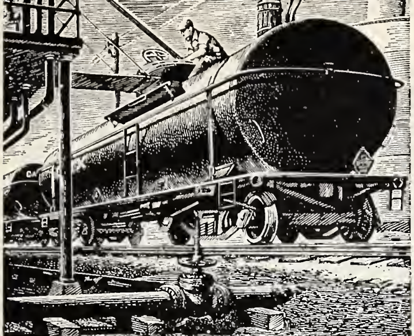
rails are firmly spiked to heavy wooden crossties. The road is carefully maintained. There are still more than 200,000 grade crossings which should be replaced with underpasses or overpasses, or protected with greatly improved signal devices.

Improved signals operated automatically by electricity protect against collisions, open switches, and other hazards.

The modern passenger train is the safest and most luxurious means of travel by land, and much faster than bus or automobile. It provides air conditioning, comfortable seats, clean toilets and dressing rooms, comfortable berths or beds, privacy for those who wish it, good food, and sometimes entertainment. These trains roll smoothly on smooth tracks and roller bearings. They are pulled by powerful steam, Diesel, or electric engines.

The freight trains move such materials as coal, wheat, corn, ore, lumber, machinery, and many other products which could not be shipped by any other means. For every dollar taken from passengers, the railroads take six to eight dollars from freight. Special cars are provided to transport milk, fruit, oil, ore, and other special products. Weight of trains is being reduced by use of steel alloys, bearings are being improved, and more powerful engines are used to give better and cheaper service. Some trains have power provided by engines consisting of a Diesel engine or steam turbine which operates an electric generator. The current is delivered to each car, which has an electric motor to drive it. Some local trains use Diesel-electric power.

How do trucks and tractors operate? Ordinary trucks are heavy automobiles with specially made bodies. Other trucks con-



General American Transportation Corporation

The tank car and refrigerator car are only two of several special types developed for safe hauling of freight by railroads.

sist of a tractor, which carries no load, but which pulls one or more trailers. Most long-distance trucks are tractor-trailer combinations. The smaller trucks use gasoline engines for power, but those of more than three tons often have Diesel engines. Large trucks create special problems on the roads, for they generally move more slowly than automobiles, and are so large that they block the view and are difficult to pass. They do provide necessary transportation.

A tractor for special purposes, such as plowing or moving logs, is not greatly different from an automobile. Small garden tractors are operated by walking behind them. Farm tractors are operated like automobiles. Tractors have gears arranged for power rather than for speed. A tractor's high gear is about the same as an automobile's intermediate.

Tractors may have one of three types of wheels. The rubber tire wheel is perhaps commonest, but large steel wheels with metal crosspieces called lugs are still common. The track-laying tractor has a chain gear passing over wheels, one of which provides power. This chain gear has flat metal plates with lugs for treads. It can travel on soft and uneven ground where no other type of vehicle can go. This tractor may be steered by turning the two tracks at different speeds, or by use of front wheels.

How is the streetcar operated? In the larger cities the streetcar provides the safest and cheapest transportation. Its chief advantage is that it carries many passengers in a relatively small space on the street. The location of tracks in the middle of streets blocks other traffic and is a hazard to passengers.

The electric street railway is being replaced by the bus because of the greater weight of the streetcars and because of the cost of laying tracks upon which taxes are paid. Buses can pass each other and don't require switching.

The streetcar, or trolley, is

Caterpillar Tractor Company

For the heaviest local hauling, tractors are employed. These three huge logs are on their way to a sawmill.

driven by electric motors. Electricity may be supplied to the car in three ways: from an overhead cable, from a cable laid underground, or from a third rail laid beside the track. Electricity may also be provided by the Diesel-electric system within the car itself.

The New York subway runs beneath the streets, buildings, and rivers of the downtown section. In the suburban areas the subway trains run aboveground.

Street Railways Advertising Company

The motorman operates the car by a controller which regulates the flow of current. The direction of the car, as well as the speed, may thus be controlled. The car is started gradually by admitting the current through resistance coils and by connecting the two motors—first in series, then in parallel.

A million-dollar experimental streetcar has been developed and put into successful use. It has the desired modern transportation conveniences—quick pickup, air conditioned, improved springs and bearings, quiet operation, and a streamlined body.

What are some other means of transportation? The bus is so familiar to all that it needs no description. In some cities electric trains operate in subway or on elevated tracks. Gas and oil

are transported in pipelines. And even the horse and mule have their uses for pulling delivery wagons, for riding in rough country, and for pulling farm machines and wagons.

Exercise

Complete these sentences:

Friction is reduced on trains by —1— in wheels and by improving the —2— on which they run. Slight grades help to overcome —3—. By making trains lighter loss due to —4— is reduced in stopping and starting. The safest means of transportation is by —5—. Most freight on land is carried by —6—. Smoke is kept out of passenger trains by —7—. Any machine which is used to pull another is a —8—. The —9— tractor can travel best on soft ground. The streetcar is controlled by regulating —10—.

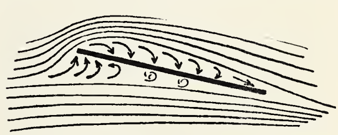
7. Why do airplanes fly?

The airplane is today one of the essential factors in national defense and in transportation. While the total number of passengers carried and the total number of tons of freight hauled is not great compared to the volumes carried by trucks, automobiles, and trains, it still is considerable.

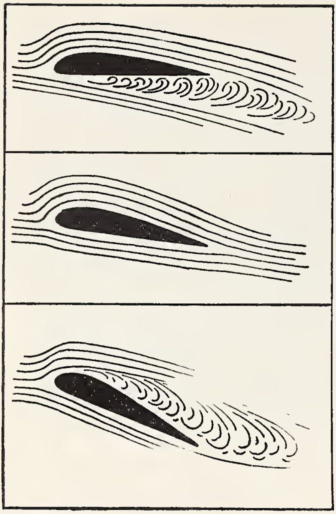
What forces act on airplanes in flight? When an airplane is in flight there are forces acting on it in four directions. The downward force is gravity or G. The force which causes the plane to be lifted into the air is lift. The force of the propeller or jet which thrusts the plane forward through the air is called thrust. All the forces which tend to drag the plane down or back are called drag. No matter what a plane is doing in the air—flying straight, turning, looping, or diving—these forces act at all times. When they are in balance the plane flies in a straight line at constant speed.

In order for the plane to rise lift must be greater than G. When G is greater than lift, the plane tends to fall. In order for a plane to gain speed thrust must be greater than drag. The lift of airplane wings is dependent upon their forward motion through the air.

A kite remains in the air when it is held at the proper angle in a strong wind. The air flowing on the lower side of the kite exerts a greater force than does the air flowing along the upper surface. Because of the inertia of the moving air, the air which is deflected [turned aside] upward by the leading edge of the kite does not immediately return to a position close to the upper surface. There is, as a result, an area



Flow of air around a kite is uneven and shows evidence of many eddies. Although a kite remains in the air because of pressure upon its lower side, its flight is jerky and unsteady.



The black figure represents the cross section of an airplane wing. When moving forward at the correct angle (*center*), the flow of air around the wing is smooth. When the wing is tilted at too small an angle (*top*) or too large an angle (*bottom*), eddies are set up and the even pressure beneath the wing is disturbed.

of reduced air pressure along the upper surface of the kite, and the kite tends to rise against gravity. The kite flies unsteadily because of eddies of air around it.

To overcome the tendency of the air to form eddies, the shape of the airplane wing is planned to cause the air to flow from it smoothly in a streamline fashion. The leading edge is rounded, with the more convex curve on the upper side. The leading edge is thicker than the trailing edge. The lower surface of the wing is either slightly curved or straight, depending upon the speed for which the plane is designed.

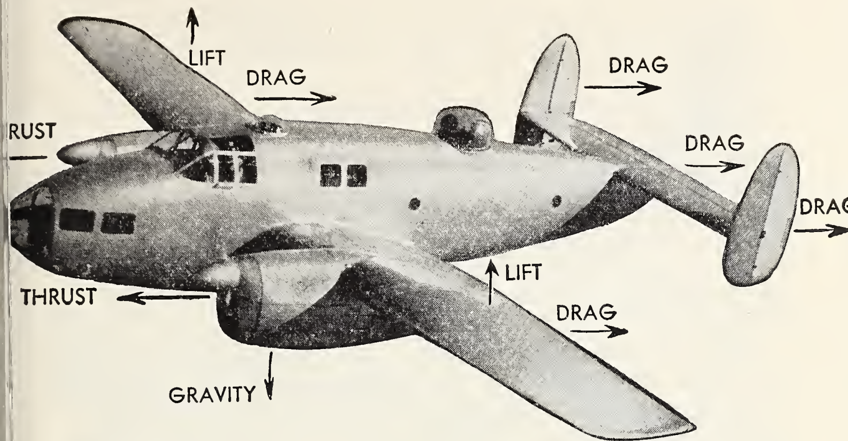
The airplane wing is designed primarily to reduce the air pressure above the wing, and to increase it below the wing. The distance around the top of the wing is greater than the distance around the bottom. When a flowing gas is caused to increase its speed, it loses pressure. In order to get around the longer distance above the wing, the air is forced to speed up and to lose pressure. Thus a partial vacuum is formed above the wing.

If an airplane rests on the ground facing a strong enough wind, it will rise into the air like a kite. The same result is obtained when the air is still and the plane moves forward through it. The movement of air around the plane is called relative wind.

Any surface designed to create and use differences in the pressure of moving air is called an airfoil. The wing is an airfoil. Other airfoils are the propeller, the elevator, the tail and rudder, and other control surfaces.

As the wing is moved forward into the air, the amount of lift increases with the square of the speed.

The wings are tilted with the leading edge higher than the trailing edge. If the angle is too great, eddies form along the upper surface. If the angle is too small, the eddies form on the lower side of the wing. Eddies upset the balance between the pressure beneath the wing and the partial vacuum above it.



Fairchild Aircraft

In order for a plane to remain in even flight, the four forces must be kept in balance.

What produces forward motion? The propeller may be thought of as a section of a screw, so made that its pitch pushes it through the air just as a wood bit bores through wood. The thrust of a propeller depends upon its velocity, its length, its pitch, and upon the number of revolutions it makes per minute.

A propeller has thrust because it is the same as a wing in its action—that is, air pressure is decreased in front of the propeller and increased behind it. The rounded side of the propeller is in front, the flat side to the rear.

Drag is the result of eddies caused by the inertia of the air and of the friction of the plane moving rapidly through the air.

If you hold a square cardboard, with its flat side toward the air flow, at arm's length from a window of a slowly moving automobile, you will find that the air offers only slight resistance to the card. If, however, the speed is increased, it soon becomes impossible to hold the cardboard in the position described. Since the resistance of the air increases with the square of the speed, increasing the speed five times increases the air resistance 25 times.

Because airplanes rarely fly at speeds of less than 100 miles an hour and often fly at speeds of 300 to 500 miles per hour, the problem of wind resistance is of utmost importance. A small rod which is shaped to resist wind has the same power to retard movement at high speeds that a small sail would have at low speeds. At present speeds a very real problem of streamlining exists in relation to airplanes.

Some drag is necessary. In order to force the air to flow unevenly around the curved wing it must be pushed aside by the front edge of the wing. The resistance of the air to the wing drags on the leading edge of the wing. This wing drag is changed to lift as the air above the wing gains in speed. It is also necessary for the propeller to create drag in order to produce thrust.

Drag on most other parts of the plane is wasted. The front surfaces of all other parts of the plane must push the air aside. Any irregular surface creates eddies and friction in the air. Because of this, modern planes designed for high speed flight have landing gear and all other equipment possible withdrawn into the plane in flight. Only the small, low-speed planes still have landing gear which is not retracted [drawn up] into the plane. It is said that the landing gear, when in landing position, of the average airliner creates more waste drag than the rest of the plane.

In your model airplanes, you do not find much need of streamlining unless you make them capable of fairly high speeds.

DEMONSTRATION:
HOW DOES AIR LIFT A CURVED SURFACE?

What to use: Book, sheet of paper.

What to do: Crease the paper in the middle, crosswise. Fold it. Curve one-half of the paper to make it convex. Put the flat half inside the cover of a book. Blow on the folded edge of the paper.

What was observed: Describe the movement of the paper.

What was learned: Why did the sheet of paper rise?

Exercise

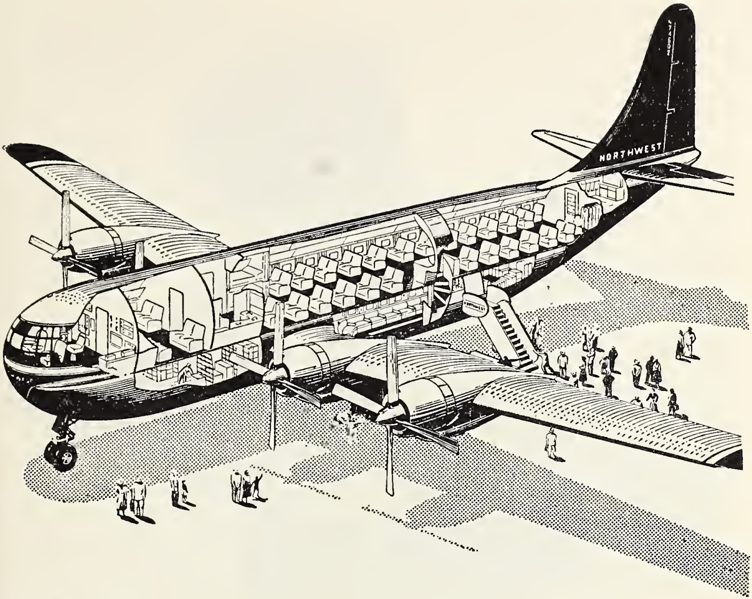
Complete these sentences:

Lift is provided to airplanes by creating differences in —1— upon wing surfaces. The upper surface of a wing is always —2— in shape. As air flowing around the wing increases in speed, its —3— is reduced, creating a —4— above the wing surface. The upward force of air pressure on the wing provides —5—. The propeller is an —6— which changes differences in air pressure into a force called —7—. Resistance of the air to the moving plane causes a force called —8—. The downward force on the plane is —9—. Wings, the propeller, and controls are examples of the —10—.

8. How are airplanes constructed?

The airplane is made of many and complex parts. Of these, the main parts are the power plant, consisting of the engines and propellers, the lifting surfaces or wings, the body of the airplane, and the controls. Then also, there are the many instruments which assist the pilot in guiding and flying the plane.

What is the airplane power plant? The four-cycle gasoline engine and the jet engine are the standard airplane power plants. The gasoline engine used is similar to that used in automobiles.



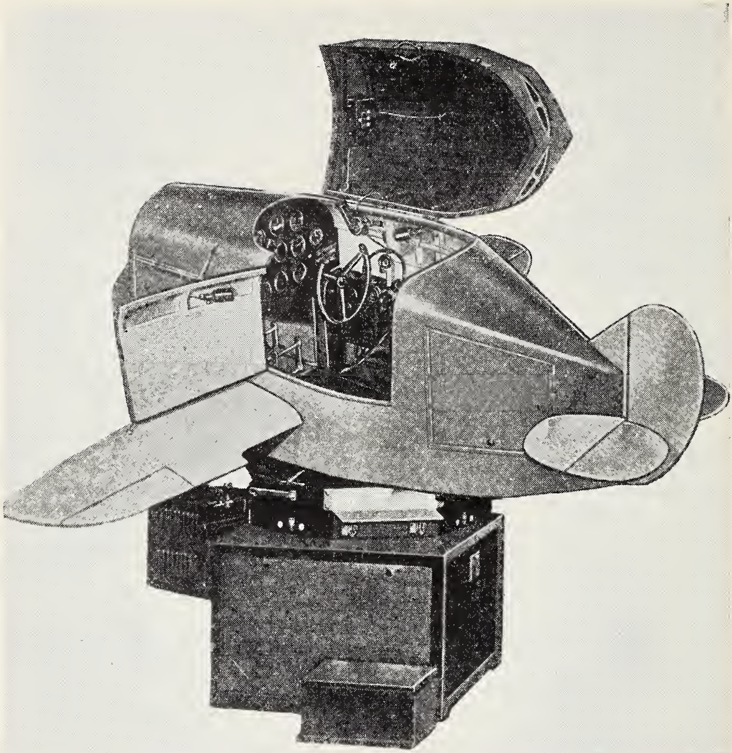
Northwest Airlines

The comfort and convenience, as well as the passenger load, is in part determined by the interior design of the airplane. Locate the pilot's seats, the passenger areas, the galley, and the baggage area.

In the radial type of engine the cylinders are arranged like the spokes of a wheel. The number of cylinders may range from 5 to 10, each separate from the rest except where they join in the center at the crankcase. The cylinders may also be arranged in a line, like the standard automobile engine, or in two lines, like the V-type engine. Other arrangements are in three lines, called the W-type, and in four lines, called the X-type, and the pancake engine.

Because of the low pressure of the atmosphere at high altitudes, it is necessary to use a supercharger to provide a sufficient supply of oxygen to the engine. The supercharger is a fan or blower operated at high speeds, making from 12,000 to 30,000 revolutions per minute, and is operated by an exhaust-driven turbine or by a separate engine.

For high-altitude flying a radiator is often used to cool the engine. Instead of using water in the radiators, another liquid may be used. Its high boiling point makes it superior to water and permits the radiator to be decreased in size. For low-altitude flying and for smaller planes, the air-cooled engine is superior. Air-



Link Aviation, Inc.

This instrument trainer is used for teaching blind flying. The cover leaves the pilot entirely dependent on the instruments to know how the trainer plane is "flying." This trainer model plane reacts to controls—throttle, pedals, wheel—like a real airplane.

cooled engines are usually of the radial type.

The jet engine may be used without a propeller, or in combination with a turbine operated by the jet which turns a propeller. The jet plane is more effective in regions where air pressure is reduced, for the action of the jet does not depend upon air resistance as a propeller does. At 50,000 feet the air is only about one-sixth as dense as at sea level. The upper limit to which a plane may fly is called its ceiling. Because the upper air is thin, planes designed for stratosphere flying are quite different in many ways from ordinary planes. Jet or rocket planes will eventually be used for most high-altitude flying.

How is the airplane built? The fuselage [fū′zĕ·lĭj], which

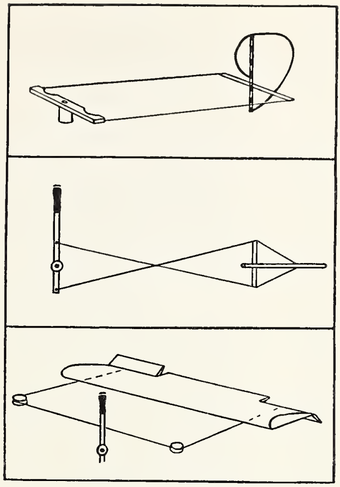
contains the power plant, the cabin, and cargo space, is the body of the airplane. To it are attached the wings, tail, and landing gear.

The type of landing gear depends upon the use to which the airplane is put. The wheel type is commonest for land planes, with the wheels arranged like those of a tricycle. For flying boats, either boat or float type of landing gear is used. Skids and ski-type gear are also sometimes used. An amphibian may have both floats and wheels, enabling it to land on either land or water.

Experimentation on different types of wings continues. The flying wing, in which all parts of the plane are placed inside the wing, is one of the newer ideas. The helicopter has a rotor which combines the work of propeller and wing. For superspeed planes, which fly at the speed of sound or faster, the wings have knife-like front edges, and rather flatly-convex upper surfaces. The ordinary wing is constantly improved by strengthening and making lighter internal bracing and struts, and by improved design. Practically all planes today are monoplanes—that is, they have only one set of wings.

The cabin of a modern airliner offers comforts and conveniences similar to those of good buses. The small, individual plane is developing comforts similar to those of some automobiles.

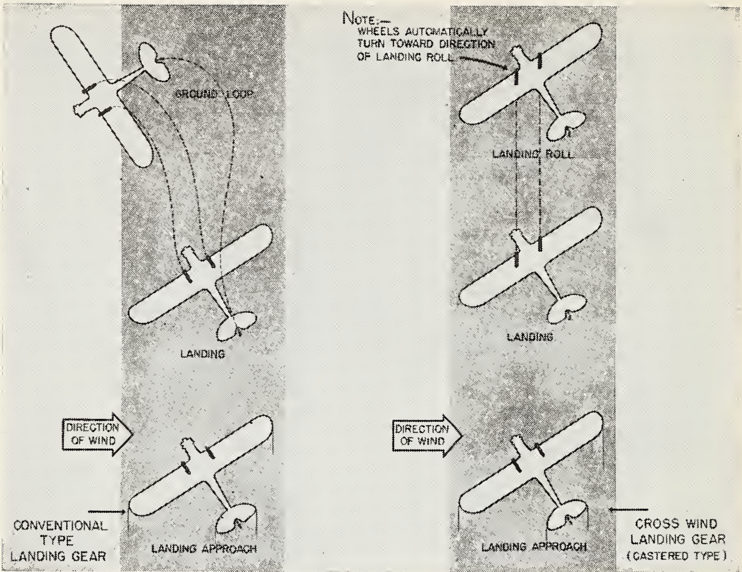
How do the controls work? There are three controls used



This diagram shows the controls of an airplane in their simplest form. The rudder (*top*) controls movement to left or right. The elevator (*center*) controls movement up and down. The ailerons (*bottom*) are used in turning and to keep the wings level.

with the airplane: the rudder, the elevator, and the ailerons [ā′lĕr·ŏn]. The rudder controls flight in a course either straight ahead, left, or right. It acts upon the air in the same manner that a rudder of a boat acts upon water—that is, it serves as an inclined plane upon which the air pushes. The elevator acts as a rudder but in a direction parallel to the ground. The ailerons are hinged flaps, attached to the rear of the wings, used either to keep the wings level or to cause the airplane to roll by turning one wing up and the other down.

The rudder usually is operated by a foot bar or pedals, the two being connected by wires. The



Goodyear Tire and Rubber Company, Inc.

By developing pivoted landing wheels, it is now possible for a plane to take off or land across the wind. An airport thus needs only one landing strip instead of several. Properly equipped planes may land much nearer the center of cities than was possible when several landing strips were required.

steering bar operates in a manner somewhat the same as that of a sled. The elevator is operated by the stick, which is pushed forward to bring the nose of the plane down. To bring the nose of the plane up, the stick is pulled back, raising the elevator. The ailerons are controlled by a stick or wheel.

What instruments are used in flying? While the number and complexity of flying instruments is so great that we cannot hope to explain them fully, it is worth while knowing how flying is safeguarded.

Two devices serve to explain how altitude is measured. The aneroid-type altimeter is an aneroid barometer with a scale reading in altitude above sea level. It operates upon the well-known principle that air pressure is reduced as elevation increases. This type of altimeter has two serious flaws: It varies with changes in weather and gives elevation above sea level instead of above the ground.

The second type of altimeter is called the radio-echo altimeter. A tiny radio sending station is located on the wing tip. Short radio waves are sent to the ground and reflected back. A re-

ceiving set receives both the sent wave and the echoed wave. The greater the distance to the ground, the more the waves are out of step. The altitude is measured by a dial. Radar works on a similar principle, except that the reflected radio wave shows a picture on a screen.

Other instruments measure the rate of climbing and of losing altitude. There are various devices used for determining the speed of the airplane in relation to the air and to the ground. As you know, an airplane traveling 100 miles an hour with the wind is actually going faster than is an airplane traveling 100 miles an hour against the wind.

There are also various types of compasses in use. One type is a magnetic compass. Another is made up of small coils which are rotated to cut the earth's magnetic field.

Another compass contains a gyroscope [jī′rȯ·skōp]—a toplike wheel which spins with sufficient inertia to keep it from being turned rapidly. Since the gyroscope resists being turned, it is a valuable device in measuring the rate of turning. It is also used to keep the controls of the planes steady without the pilot's attention.

Other instruments indicate whether or not the plane is level, how far the nose is above or below the tail, and whether the plane is banking or not. Instruments also inform the pilot of the number of revolutions per minute made by the propeller, of the pressure of the oil, of the amount of gasoline, of the flow of fuel, of the engine temperature, and the current produced by the generators.

Finally, there is the radio equipment. Transport planes are so equipped that they can follow radio beams which direct them on their courses and to the landing fields. This equipment is quite complex in its operation, but with it pilots frequently land planes without being able to see anything but their instrument boards. Devices are in use which take the landing of the plane from the hands of the pilot and permit its complete control by radio from the ground. Such control sometimes increases safety of landing.

DEMONSTRATION: WHAT IS A GYROSCOPE?

What to use: Small gyroscope, string, stand.

What to do: Spin the gyroscope by winding a string around the shaft and pulling it sharply. Stand the spinning gyroscope upon its stand. Balance it upon the string held tightly in the hands like a clothesline. Hold the gyroscope in the hand, and turn it quickly.

What was observed: Describe the action of the gyroscope.

What was learned: What principle explains the stability of the gyroscope? Why does it resist falling and turning?

Exercise

Complete these sentences:

The airplane engine is a —1— cycle, —2— combustion type engine. At high altitudes more air is

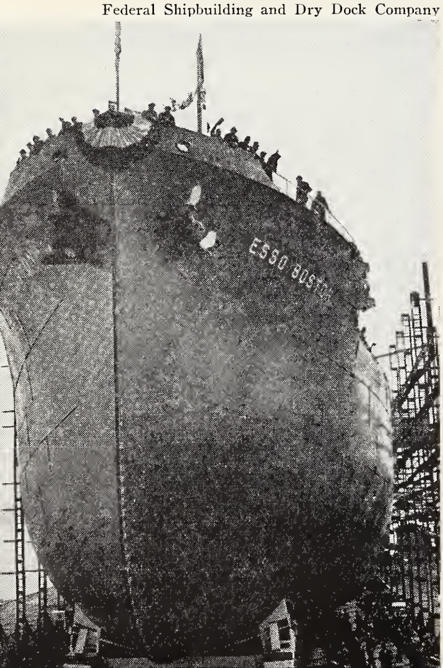
supplied to the engine by the —3—. The engine is —4— cooled in smaller and low-altitude planes, and usually —5— cooled for high-altitude and larger planes. The standard airplane wing system today is the —6—. The —7— is the body of the plane. Airplanes are turned right or left by the —8—, up or down by the —9—, and held level by the —10—. The use of —11— beams permits automatic control. A device for measuring altitude is the —12—.

9. How are ships used in transportation?

Ships are of considerable use on inland waters and are the only adequate means of transportation across oceans. Almost a fifth of the freight moving between cities is carried by ship. Boats range in size from the tiny duck-boats used by hunters to the giant ocean liners which are able to carry the population of a small city.

Ships are built on tracks and launched by sliding them down the track into the water. This picture shows the shape of the hull and the method of joining plates by riveting.

Federal Shipbuilding and Dry Dock Company



Why do boats float? The weight of a boat must be less than the weight of an equal volume of water. Fresh water weighs $62\frac{1}{2}$ pounds per cubic foot; salt water weighs slightly more. A boat will float if it weighs less than this per cubic foot of volume. The weight of an iron boat is only the weight of the iron. The volume of the boat, if it is kept right side up and empty of water, is the volume of the iron plus the volume of the air inside the boat. The air space reduces the density of the boat.

If you make a boat by folding a sheet of aluminum foil, it will float. But if you crumple the aluminum foil into a ball and throw it into water, it will sink. You reduce the volume by rolling the foil into a ball.

Density, as you know, is the weight of a material for a given unit of volume. The density of water is one. In the metric system one cubic centimeter of water weighs one gram. If a cubic centimeter of another material, stone for instance, weighs three grams, its density is three. Density equals mass over volume.

In the English system we must

do more work to measure specific gravity, which amounts to the same thing as density. If a cubic foot of water weighs $62\frac{1}{2}$ pounds and a cubic foot of another material weighs 250 pounds, we divide 250 by $62\frac{1}{2}$ to find the specific gravity of four.

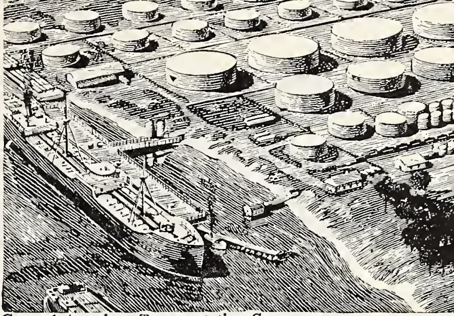
$$\textbf{Specific gravity} = \frac{\textbf{weight of the object}}{\textbf{weight of an equal volume of water}}$$

Boats are so built that the center of gravity is low. The center of gravity is the point around which the weight is equally distributed. If the center of gravity were above water, the boat would have a tendency to roll; and if it were much above water, the boat would roll over, and possibly would sink.

What are the different kinds of ships? A liner is a ship which maintains a regular ocean route. The size of ships is rated in tons of displacement. The largest liners displace around 50,000 tons of water, the smaller ones about 10,000 tons. Liners range in length from 400 to 900 feet.

The liner is made of a steel frame and covered with a riveted or welded steel hull. Inside the boat are many compartments. The power is obtained from either steam or Diesel engines. The most advanced type of steam engine has an oil-burning furnace to generate the steam which supplies power to the turbines. Some boats have steam engines of the triple-expansion type instead of turbines.

The funnels or smoke stacks of



General American Transportation Company

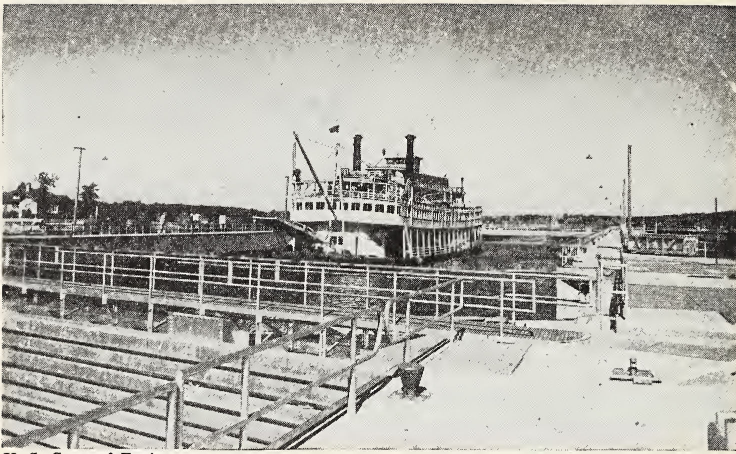
Transportation of oil requires not only tanker ships and tank cars, but also huge storage tanks.

the bigger liners are of no use whatever. Oil burners do not require funnels of this type. More than half the smaller boats are powered with Diesel engines.

Ships are driven through the water by a screw-type propeller, which is made of an alloy resistant to the action of salt water. The propeller usually has three removable blades. Thus if one blade is broken, it may be replaced without removing the entire propeller. The propeller and rudder are placed at the stern or back of the boat.

From 20,000 to 50,000 horsepower are required to operate the larger liners at speeds of 15 to 25 knots. A knot is 6080.20 feet per hour.

A tramp is a steamboat which has no regular schedule but takes whatever freight is available and maintains a schedule that suits each voyage. Ocean-going tramps average about 350 feet long and have a displacement of about 3000 tons. They are particularly interesting while loading and un-



U. S. Corps of Engineers

This Mississippi river steamer is within the lock chamber. The water will be drained out until the steamer is lowered to the level of the water below the dam.

loading because of the winches, derricks, engines, and coils of rope which are used for handling freight. Tramps maintain an average speed of about nine knots. Most tramps are driven by Diesel or regular piston-and-cylinder steam engines.

The hold, or hollow part, of the boat is designed to carry freight. As much space as possible is made available for goods—lumber, grain, chemicals, fibers, tar, iron, cattle, or whatever may be picked up.

Great Lakes freighters and ore boats average from 450 to 600 feet in length and have a displacement of 15,000 to 20,000 tons. The advantage of shipping by water is the low cost made possible by the low resistance of water to boats. It is not necessary to build roads or tracks for boats.

A trawler is a fishing boat, between 75 and 150 feet in length, that drags a net through the water. These boats also transport fish from slower fishing boats to the land as fish are caught.

A tug is a small but very powerful boat. It is practically all engine and hull. The larger tugs are from 1000 to 1500 tons, and the smaller are scarcely larger than motorboats. Tugs have two main uses. They push and pull liners to their docks. The liners are so large that they cannot move safely under their own power in harbors. Tugs also move barges, which are flat shells of steel used to haul coal, wheat, ore, garbage, fish, or almost anything that can be moved by boat.

Many old paddle-wheel boats are in use as excursion steamers or for short freight hauls. Many

small, gasoline-driven boats on the inland waters are of value for sport, transportation of a few passengers, and for fishing. Ferries are used in a number of places where bridges are not practical.

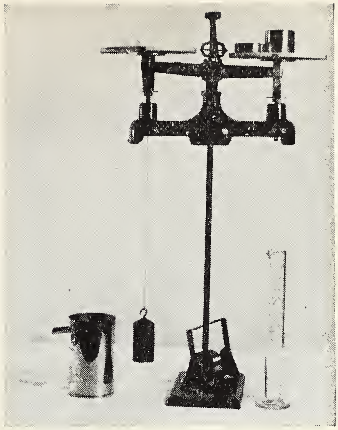
How are locks used in navigation? Locks are used for two purposes, to get ships up and down elevations, and to make the river help to carry the ship upstream. A lock consists of a canal with gates at both ends. To raise a boat to a higher level it is moved into the lock. The gate is closed behind it, and water is run into the lock until it is level with the water on the upper level. The gate at the upper end then is opened, and the ship goes on its way on the new level. The process of lowering a ship is the reverse. The lock is filled, the boat enters, the gate is closed behind it, and water is run from the lock until the boat reaches the lower level.

In river navigation currents are particularly troublesome. In going upstream the boat must lift itself against gravity, and must overcome the friction of running water. In going downstream currents make ships difficult to handle. By building dams and locks along rivers it is possible to operate boats in fairly still water at all times.

DEMONSTRATION: HOW IS SPECIFIC GRAVITY MEASURED?

What to use: Weights, block of wood, balance, jar, pan.

What to do: Weigh carefully the block of wood. Fill the jar completely full of water, first placing the jar in the pan. Carefully float the wood in the jar, catching the water that overflows. Weigh the water.



This is one type of apparatus that may be used to perform the demonstration.

Repeat the experiment, filling the jar as before, but lowering a large weight into the water with a spring balance. Note the reading of the spring balance before the weight touches the water and after it is completely covered. Then again weigh the water in the pan.

What was observed: Make a record of the weights of the block, the water, and the weight. What does the block weigh in water? The weight? How much weight did the block lose? To find the specific gravity of the weight, divide its weight by its loss of weight.

What was learned: Is the loss of weight in an object in water equal to its own weight in air or to its loss of weight in water?

Exercise

Complete these sentences:

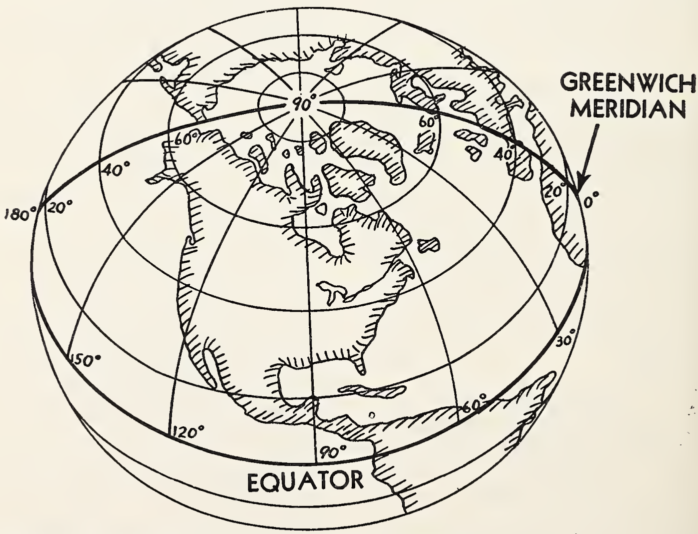
A floating object displaces its own —1— of water. Water weighs —2— pounds per cubic foot. Hulls of large ships are made of —3—. The specific gravity of water is —4—. The loss of weight of an object in —5— equals the —6— of the water displaced. A small boat used to move liners is a —7—. The largest liners have a displacement of about —8— tons. The fastest liners travel about —9— land miles an hour.

10. How does transportation depend upon navigation?

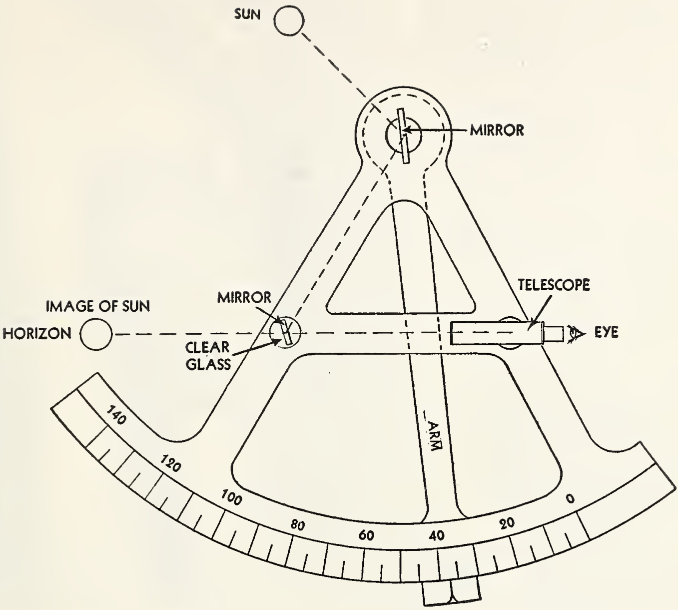
Navigation is the act of setting up a course for a ship or airplane, and directing the ship or plane on its course. Common aids to navigation are the compass, the chronometer, the sextant, radio equipment, maps, and charts.

How do we locate places? Simple methods of locating places, such as locating direction by the sun or North Star, are not sufficient for transportation. If an airplane flying at night is to reach a small island navigation must be accurate. Places everywhere on earth are located by their latitude and longitude.

Latitude is the distance in degrees north or south of the equator. Any line drawn around the earth is a circle. Hence latitude is measured in degrees (°). There are 360 degrees in a circle. A degree is divided into 60 minutes (′), and a minute is divided into 60 seconds (″). All points on the



Longitude is measured from the Greenwich meridian.



The sextant is an instrument used to determine latitude on board ships.

equator have a latitude of 0 degrees. The poles have a latitude of 90 degrees. Points between the equator and the poles have latitudes ranging from 0 to 90 degrees. The city of Minneapolis, Minnesota, has a latitude of 45 degrees. It is halfway between the equator and the North Pole. A circle drawn on the earth parallel to the equator is called a parallel of latitude. All places on the same parallel have the same latitude.

Longitude is the distance east or west from the prime meridian that runs through Greenwich, England. A meridian is an imaginary line that extends from pole to pole. In measuring longitude, the Greenwich meridian is called zero degrees; a point on the opposite side of the earth is 180 degrees. Intermediate points have longitudes ranging from 0 to 180 degrees east or west.

At the equator a degree of longitude equals 69 miles. A second equals about a fifth of a mile. By knowing the latitude and longitude, it is possible to locate a ship within a few hundred yards. As one goes north from the equator, the length of the degrees of longitude becomes shorter.

How is latitude found at sea? In order to find latitude, sailors use an instrument called the sextant. It is used to find the height of the sun above the horizon at noon. This height is expressed in degrees.

Rockwell Kent, for the American Export Lines Collection

"Shooting the sun" is one of the most important ways of determining location. The device used is the sextant.

The sextant is pointed toward the sun at noon. As shown in the diagram, the light from the sun strikes the mirror, from which it is reflected to another mirror. On its way, the light passes through dark glasses which reduce the glare so it will not hurt the eye. One half of the second glass is a mirror, the other half is made of clear glass. As a person looks through the telescope, he sees two things: the image of the sun, which has been reflected by the mirror half, and the horizon, through the half that is made of clear glass. The arm of the instrument is moved till the image of the sun just touches the horizon. The angle is then read from the scale at the bottom of the instrument. This angle is the height of the sun. From this angle, and by using tables, the latitude of the place may be found.

How is longitude found at sea? The longitude of a place may be determined by comparing its solar time with the solar time of Greenwich. A difference of one hour equals a difference of 15 degrees longitude. For example, when it is six o'clock in the morning at Chicago, it is twelve noon at Greenwich. Multiplying this difference of six hours by 15, we get 90 west longitude for Chicago.

In order to find longitude at sea, ships carry two clocks. One

is set to keep Greenwich solar time. It is called a chronometer [krô·nŏm′ê·tẽr]. The other clock keeps local solar time. This clock is kept accurate by making observations of the sun and by radio signals. The longitude is determined by finding the difference in time between the two clocks.

What is time? Measurement of time is based on the daily rotation of the earth. The day is divided into 24 hours; each hour is divided into 60 minutes; and each minute is divided into 60 seconds.

There are two ways of determining when the earth has completed one rotation: by observing some star or by observing the sun. The time obtained by observing a star is called sidereal [sī·dēr′ê·ăl] time, that obtained by observing the sun is called solar time.

The observations in this country are made at the Washington Naval Observatory. The observations are made by means of a small telescope, so mounted that it turns only from north to south. It can be made to follow the meridian and is used to determine when a star crosses the meridian. Because this crossing of the meridian is called a transit, the telescope is called a transit instrument.

The telescope is pointed toward a certain point in the sky, and the exact time is taken when a certain star is seen in the telescope. Twenty-four hours later the same star is observed again. And when it again crosses the meridian, that is the end of a sidereal day. The standard clock in the observatory is then set to correspond with this time. Sidereal clocks are numbered from 1 to 24, instead of from 1 to 12.

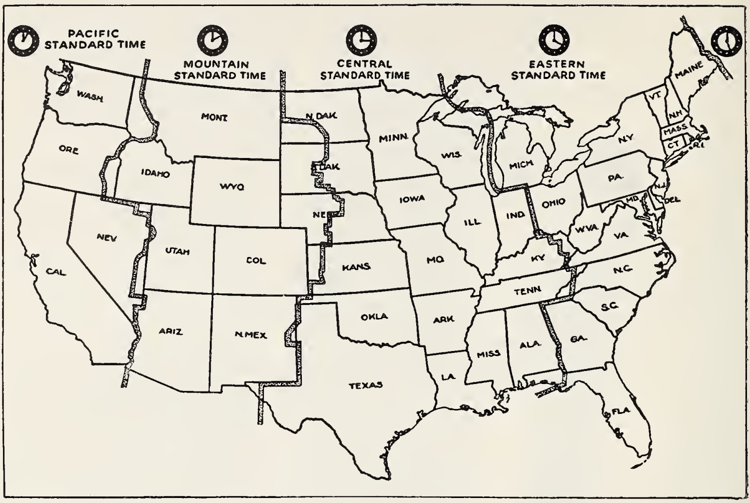
When observation is made of the sun to determine when the earth has completed a rotation, the result is known as a solar day. This day is about four minutes longer than the sidereal day because at the same time that the earth is rotating, it is also revolving around the sun. In a day the earth has moved a little way in its orbit around the sun.

Because the transit of a star can be more exactly observed than that of the sun, the observers at the Washington Naval Observatory first find the sidereal time. This is easily changed to the mean solar time. The correct time is then sent out to the country and to ships at sea by means of telegraph and radio.

Solar time is constantly changing as one travels east or west.

In former days each town had a time different from that of towns east or west of it. When people traveled little, this difference did not cause much trouble. But as railroads were built and people traveled more, this difference in time became confusing. Therefore, in 1883 a system of standard time was adopted.

Now, instead of having hundreds of different times as formerly, there are only four times. Since Washington is in the Eastern time belt, cities in the other belts must subtract one or more



This is a standard-time map.

hours according to their locations, to obtain correct time. Those cities in the Central zone subtract one hour; those in the Mountain zone, two hours; and cities in the Pacific zone, three hours. If it is 12 noon in Washington it is 11 A.M. in Chicago, 10 A.M. in Denver, and 9 A.M. in San Francisco. In traveling across the country, one must set his watch back or forward an hour as he enters each belt. Traveling from east to west he sets his watch back an hour for each time belt; traveling from west to east one sets his watch ahead.

How are maps used in navigation? There are many ways of making maps, but all maps are misleading because they attempt to show on a flat piece of paper the shape of a curved surface. For areas as small as states this error is not serious.

What looks like the shortest route on a map may actually be hundreds of miles farther than one apparently longer. The shortest distance between two points is on the great circle, that is, a line drawn through the two points which if extended around the globe would complete a circle. Thus the great circle from San Francisco to London would pass over Hudson Bay and Labrador. Yet on the commonest flat map the shortest distance seems to pass near Kansas City and Boston.

The only true representation of the earth is a globe.

Maps are used to give correct latitude and longitude of places, to show airports and harbors, to show depth of water, to locate roads and railroads, to show elevation and location of mountains, to show weather, and for

many other purposes. Navigation without maps would be very difficult.

Exercise

Complete these sentences:

A circle has —1— degrees. Latitude is measured from the —2— longitude from —3—. The clock on which Greenwich time is kept is called a —4—. Latitude is found by use of a —5—. Time measured from a star is called —6— time. A —7— time belt is —8— degrees wide. One sets his watch —9— when traveling east. The shortest distance between two points on earth lies along a —10—.

A review of the chapter

The scientific laws on which transportation is based are the laws of motion and the laws of conservation of energy. An object at rest remains at rest, and an object in motion continues in motion in the same straight line unless acted upon by an outside force. Change in the rate of motion is in proportion to the force causing the change. For every action there is an equal and opposite reaction. Gravitation is the attraction of every object in the universe for every other object. Energy cannot be created or destroyed, but mechanical energy may be lost when changed to heat energy. Energy is released by chemical or physical changes and when controlled will do work.

In order to drive safely, drivers, and especially youthful drivers, must learn and observe rules of safe driving. Every modern transportation device is made possible by application of scientific laws.

Navigation is the planning of the course of a ship or airplane and directing it along the course. Latitude and longitude are used to measure locations of ships and to determine their courses. The sextant is used to determine latitude by determining the elevation of the sun above the horizon. Longitude is found by comparing sun time and Greenwich time, which is kept on a clock called a chronometer. The United States is now divided into four standard time belts.

Word list for study

suspension	pedestrian	tractor	gyroscope
thrust	lift	drag	specific gravity
airfoil	helicopter	fuselage	sidereal
lock	navigation	great circle	altimeter
clutch	fluid coupling	differential	sextant
ball bearing	pendulum	streamlined	aileron
hydraulic brake	brake shoe	transmission	chronometer
clover-leaf	reaction time	rudder	

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. A body at rest remains at rest, and a body in motion continues in motion in the same straight line, unless acted upon by an outside force.

B. The change in rate of motion is in proportion to the force producing the change.

C. Friction changes kinetic energy to heat.

D. Work is done when force overcomes gravity.

E. Air resists objects moving through it in proportion to the square of their speeds.

F. The amount of kinetic energy obtained from engines is in proportion to the amount of heat taken from the gases in the engine.

G. Reaction time is the time between receiving a sense impression and the muscular response to the stimulus.

H. When unequal forces act upon an object, the object tends to move in the direction of the larger force.

I. The loss of weight of an object in water is equal to the weight of the water displaced.

J. For every action there is an equal and opposite reaction.

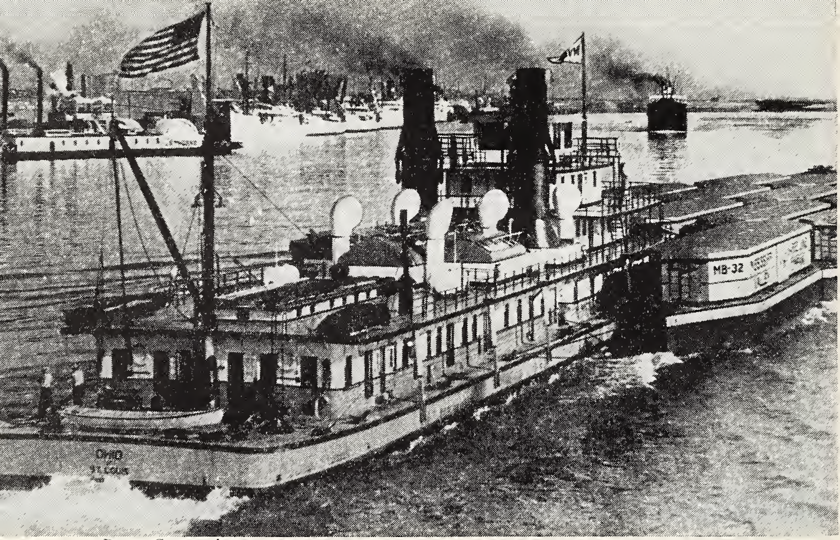
List of related ideas

1. Because the Diesel operates at higher temperatures, its efficiency is about 37 per cent compared with the gasoline engine efficiency of 25 per cent.
2. The lifting effect of air pressure causes an airplane to fly.
3. Speeding automobiles cannot turn corners rapidly.
4. Streamlining increases the efficiency of vehicles at high speed.
5. It takes from one-third to two-thirds of a second to put on brakes.
6. Brakes become hot when they stop moving trains.
7. Powerful engines are required for quick pickup.
8. Radiators are used to remove heat wasted in the automobile.
9. The airplane propeller is an inclined plane that is pushed forward by the air.
10. Boats must weigh less than 62½ pounds per cubic foot.
11. Some of the energy used in climbing a hill is regained by coasting down the other side.
12. It is expensive to stop and start freight trains.
13. Steam engines are made with triple-expansion cylinder arrangements.
14. No human being can safely drive an automobile at 70 miles an hour in ordinary traffic.
15. Tires of racing automobiles sometimes blow out because of heat.

16. Railroad tracks are banked on curves.
17. Speeds of automobiles above 40 miles an hour are not economical.
18. Every projection of a vehicle body slows forward motion.
19. The propeller blows air backward with the same force that is applied in thrusting the plane forward.
20. The hotter the exhaust gases, the more power is wasted.
21. Road grades are kept below 9 per cent.
22. Roller bearings reduce waste of power in trains.
23. The drive wheels of the locomotive tend to jerk the rails loose in a backward direction.
24. A pendulum swings upward against gravity until its kinetic energy has been changed to potential energy.
25. Brake shoes wear and must be replaced.
26. Gears are stripped from their wheels if a motor running at top speed is suddenly connected to an automobile standing still.
27. Lubricating oil is used between the parts of vehicles to save energy.
28. Curved roads are dangerous roads particulary at very high speeds.
29. A submarine has a specific gravity of more than one when submerged.
30. An airplane turns sidewise when the rudder is turned to increase air pressure on it.
31. The force of the air on a balloon is greater than the force of gravity.
32. The backward force of the gases in a jet engine equals the forward thrust on the plane.
33. To speed up we give the automobile engine more gas than is required to maintain speed.
34. If you jump from a small boat, the boat moves in a direction opposite the direction you jump.
35. The size of boats is measured by the weight of the water they displace.
36. All human beings are relatively slow thinkers in emergencies.
37. When an airplane has no power, it constantly gains speed as it falls to the earth.
38. The upper part of the airplane wing is more sharply curved than the lower surface.
39. Airplanes use more energy than do other devices for transportation.
40. The higher the speed of an automobile, the more frequently fatal the accident.

Some things to explain

1. Why has transportation made faster progress than many other branches of industrial work?
2. Why did the railroads fall behind for a time in competition with automobiles and trucks?
3. How is time important in transportation? How is correct time determined?
4. Why is the airplane more widely used than the dirigible?
5. What was the earliest use of steam for transportation?
6. Why are pedestrians responsible for about half the automobile accidents?
7. What is the most probable airplane engine of the future?



Dravo Corporation

The larger rivers of the United States provide waterways for movement of freight. This river steamer is pushing loaded barges on the Mississippi River.

Some good books to read

Carlisle, N. V. and Nelson, E., *Modern Wonder Book of Ships*

Carlisle, N. V. and others, *Modern Wonder Book of the Air*

Carlisle, N. V., *Modern Wonder Book of Trains and Railroading*

Floherty, J. J., *Aviation from Shop to Sky*

Huey, E. G., *What Makes the Wheels Go Round?*

Mixter, G. W., *Primer of Navigation*

Reck, F. M., *Automobiles from Start to Finish*

Reck, F. M., *Romance of American Transportation*

Van Metre, T. W., *Trains, Tracks, and Travel*

Van Metre, T. W., *Tramps and Liners*

Webster, H. H., *Travel by Land, Air, and Sea*

Whitney, A. W., *Man and the Motor Car*

CHAPTER

10

Communication in a Modern World

We communicate ideas not only by speech and by printing and writing but by signals and by pictures. When an airplane pilot wishes to land on an airport covered by fog or in darkness, he can direct his course by automatic radio signals. He can perhaps look at a picture of the airport on a screen which forms the pattern from radio waves. Radar [rā′där, radio direction and ranging] is used on the ground to detect planes in the air and on ships to detect icebergs and other ships.

When we turn on the radio to hear the news, we expect to hear only the news developments of the past few hours. What was news yesterday is old today. You perhaps have listened at breakfast to news broadcast directly from China, Egypt, or other places on the far side of the world. Our radio systems regularly broadcast news and information about what is happening in the United States to other countries in many languages. Sometimes our television set may show us news as it happens. And it is part of the regular television service to show you news pictures taken from film only a few hours after the events occurred.

Communication makes us members of one world insofar as we are ready to become accustomed to living with the whole world as our neighbors.

Some activities to do

1. Bring to school and demonstrate as many devices concerned with recording and reproducing sound as you can.

2. Visit the local airport to observe the control system for directing planes in taking off and landing.

3. Arrange to visit an up-to-date telephone exchange in a large city.

4. Make a model telegraph system. Use a door hinge for the armature. Wind a nail to make an electromagnet. Fasten it above the hinge. Below the hinge place another nail, where the free part of the hinge can

Northwest Bell Telephone Company

Although most telephones in cities are now dial operated, the work of the switchboard is still important in much local and long-distance communication.

rest on it. Make a key from a strip of metal and a nail. Before you actually make the telegraph set, work out a method of supporting the hinge, the nails, and of connecting the wires.

5. Arrange to visit your local theater or your school projection booth, and observe the operation of the sound equipment. Find the loudspeakers, and learn how they are wired from the projection booth.

6. Make tin-can telephones. Connect two cans with 40 feet of waxed string, stretched tight and tied through holes in the bottoms of the cans. Speak into one can while someone uses the other can for a receiver. Does sound travel through solids?

7. Arrange with a commercial broadcasting station or an advanced amateur in your neighborhood to observe a transmitting station in operation. Do not waste time listening to the radio performers, but try to find out what makes the machinery work.

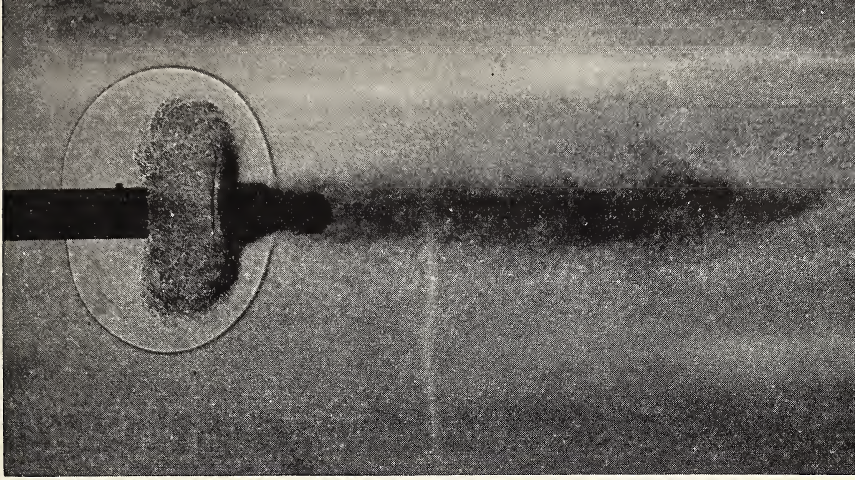
Some subjects for reports

1. The invention of the phonograph
2. The invention and development of radio
3. Tests of hearing and uses of hearing aids
4. The number of languages in the world and the number of people who speak the leading languages
5. Uses of electron tubes as rectifiers and heating devices
6. The latest types of radio-beam aircraft direction
7. The development of a written language
8. How long-distance telephone messages are sent
9. Unusual musical instruments and musical toys
10. How a television program is prepared and broadcast
11. The electron microscope

1. How do we use sound in communication?

Almost all communication is related in some way to sound. Animals communicate by calling, singing, roaring, or otherwise making sounds. Our speech is based upon the ability of our vocal cords to form certain sounds. Even our thoughts are but sounds which we think out instead of speaking.

What causes sound waves? If you pick up a tuning fork from the table and hold it to your ear, you can hear no sound. But if you strike it sharply against your heel, a sound can be heard.

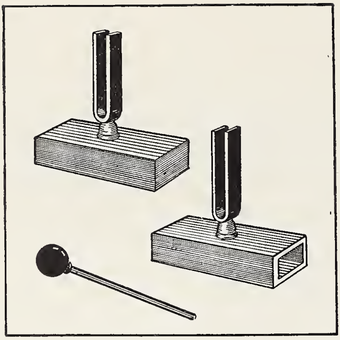


Peters Cartridge Company

This spark photograph shows a charge of shot leaving the muzzle of a shotgun. The smoke is seen just as it leaves the gun barrel. The "balloon" around the end of the barrel is a sound wave.

There are several ways of proving that a sounding tuning fork is vibrating. One of the simpler way is as follows: A piece of glass is smoked evenly. To the end of a tuning fork a fine wire bristle is attached with a tiny drop of solder or wax. Then the tuning fork is held in a clamp and arranged so that the bristle just touches the glass. Next the tuning fork is struck, and the glass moved beneath the bristle. The vibrating bristle scratches a wavy line in the soot. If another bristle is attached to a clock pendulum and caused to make marks on the glass at the same time, it is possible to count the number of vibrations made by the tuning fork in one second.

The sound wave itself is a rapidly moving layer of air molecules which are packed closely together. When photographs are taken of charges of shot leaving a shotgun, one of the sound waves produced by firing the gun appears clearly in the picture and looks like a thin balloon. This "balloon" is composed of molecules pushed close together by the force of the shot. But the molecules themselves do not shoot out from the vibrating object to form the wave. Instead, each molecule moves back and forth in its limited space. The wave is really caused by the molecules of one layer bumping the molecules of the layer next to them and then bouncing back into their places. Those of the next layer in turn bump those of the layer beyond, and so on. Where the molecules are bumping each other there is an area called a condensation. When



When one tuning fork is struck, it sets the air into vibration. The air waves are sufficiently strong to cause the second tuning fork to vibrate. If the first fork is stopped, sound from the second can be heard.

they bounce back, the air is made thinner for an instant, and this thin layer is called a rarefaction [râr′ē·făk′shŭn].

Of course a vibrating body does not ordinarily produce only one sound wave and then stop vibrating. Instead waves are sent out at more or less regular intervals. One wave follows another at distances which may vary from two-thirds of an inch to about 70 feet. The distance depends upon the rate at which the waves are produced.

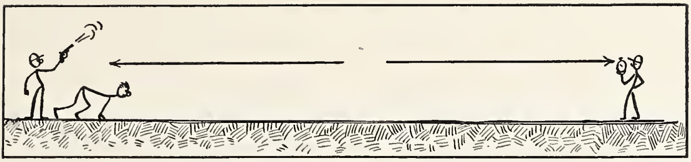
Does air carry sound? If you stand near a piano and sing a single, loud note, then press your ear against the wood of the piano, you can hear the same note from the piano. The air carried the sound wave to the wire of the piano.

Two tuning forks of the same pitch may be mounted on boxes. If one is struck, you can hear the sound coming from the second fork after stopping the vibration of the first. To be sure that the sound is carried through the air and not through the table, both forks may be mounted on cords. This experiment will not work unless the forks vibrate at the same rate. The vibrations of the first fork and of the box on which it is mounted set up waves in the air. The waves set the second fork and box into vibration. Just as a series of slight pushes, if delivered at the right time, will start a person moving on a swing, so the small force of a sound wave will move the heavy fork and box. The vibration of the boxes causes the sounds to be louder and more prolonged. Such an effect is called resonance.

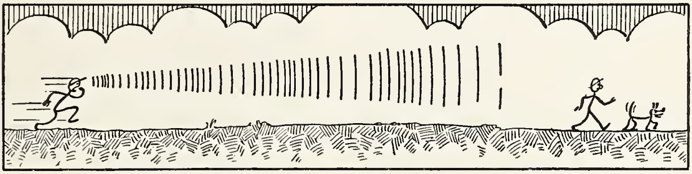
Another standard demonstration of the effect of sound on the air is performed by placing an alarm clock, set at "repeat," on a rubber pad under a bell jar. When the air is pumped out, the ringing becomes fainter and fainter. When the air is admitted again, the bell can be heard ringing as loudly as ever.

What are echoes? When a sound wave strikes a solid object, its energy may be absorbed and changed to heat or the object may be caused to vibrate or the wave may be reflected. The reflection of sound is called an echo. Echoes out of doors are usually caused by reflection of sound from a cliff or an earth bank.

Echoes indoors are usually annoying. They may travel back and forth across an auditorium



Sound travels at the rate of about 1100 feet per second. For accurate timing of races, it is necessary to start the watch by the flash instead of by the sound of the gun.



Sound waves are not powerful. Their energy is changed to heat and lost. The boy calling cannot set up waves strong enough to reach the second boy.

for a second or two, making enough noise to interfere seriously with the sound of the speaker's voice. Echoes in recording and broadcasting stations cause sounds to be changed and distorted in tone. To avoid these echoes, walls are usually covered with drapes or curtains or made of porous wallboard. Ceilings are also covered with wallboard. Floors are either covered with rugs or made of linoleum laid on felt.

What determines loudness of sound? The loudness of a sound depends upon the force used to produce it and upon the nature of the vibrating body. Loudness is measured by an electrical device which produces a current in proportion to the sound. The unit of measurement is the decibel. One decibel is the faintest sound audible to human ears, while a sound of 130 decibels is so loud as to be painful and injurious to the ears. The sound of wind over the grass is one of the least loud sounds people notice. City traffic noise is from 60 to 80 decibels. Most traffic noise is avoidable, and we should not tolerate it.

School noises vary greatly in loudness. The noise of breathing, turning pages, and slight movements in an otherwise quiet classroom may be not much more than 20 decibels. A lively discussion may bring the level of loudness up to 40 or 50 decibels. At passing of classes, hall noises may be as much as 60 decibels, but disorder, shouting, and whistling may bring it up to 80 or 90 decibels.

Although people do not do their best work in absolute quiet, neither do they do good work in too much noise. A noise level above 50 decibels is considered harmful. Nervous strain, muscular fatigue, increased tendency to

make errors, and loss of attention result from noisy surroundings. Classes should be conducted on a noise level so low that ordinary conversation is easily heard. You should not have the radio on when you study at home.

What is the speed of sound? Sound travels under ordinary conditions at the rather slow speed of 1090 feet per second. Many guns shoot bullets which travel faster than the sound of the shot. One can tell how far he is from a shot or a flash of lightning by starting to count seconds when he sees the flash and allowing about five seconds for each mile.

Sound travels about four times as fast in water as in air and about 14 times as fast in steel as in air.

Why do people sometimes need hearing aids? Even for people with normal hearing, there are many sounds too faint to hear. If an injury to the ear occurs, loss of hearing results. Usually loss starts with inability to hear high tones, those which have a frequency of 10,000 to 20,000 vibrations a second. The hearing loss may become more complete with time, until not even loud, low-pitched sounds are heard.

Injury of any part of the ear may impair hearing. If the eardrum is broken by a blow or by a sharp instrument, the sound wave encounters nothing against which it can act. Infection may destroy any part of the ear—the drum, the bones, the inner drum, or the cochlea. In the cochlea the nerve endings which respond to sound waves lie in a liquid. The cochlea is snail-shaped, and it is divided lengthwise into three divisions. The nerves lie along the dividing wall, those nearest the outer end detecting the highest-pitched sounds. If the passages of the ear become closed by growth of adenoid tissue or by infection or by pressure of the jaw muscles, hearing may be impaired. Professional swimmers and divers are very likely to suffer impaired hearing. Why?

The most common hearing aid is much like a radio. There is a microphone which picks up sound waves, an electrical device which makes them louder, and an earphone which carries the sound to the ear. If part of the ear has been destroyed, the sound may be conducted through the bones of the head instead of through the ear. To accomplish this bone conduction, the receiver is clamped against the head just behind the ear. The type of hearing aid needed depends upon the cause of the loss of hearing.

DEMONSTRATION: WHAT IS SOUND?

What to use: Tuning fork, cigar box, tuned forks or bars, pith-ball electroscope.

What to do: Tap the tuning fork. Pass it around the class. Hold the vi-

brating fork against the pith balls. Hold the handle of the sounding tuning fork against the bottom of an inverted cigar box.

Do the experiment with the tuned bars or forks as described in the text. Do any of the other experiments described in the text for which equipment is available.

What was observed: Describe briefly what happened.

What was learned: How is sound produced? How does it travel?

Exercise

Complete these sentences:

A tuning fork sets up —1— which produce —2— which travel through the air. Sound could not reach us from outer space because it does not travel through a —3—. Reflected sounds are —4—. Sound which is absorbed is changed to —5—. Sound travels —6— feet per second or one mile in about —7— seconds. The nerves of hearing lie in the —8— to which sound is transmitted from the —9— by the three —10—. The unit of loudness of sound is the —11—.

2. Why do sounds sound different?

You have observed, unless you are deaf to tones, that some sounds are high pitched, while others are low pitched. Some sounds are pleasant, others are unpleasant. Do you know why?

What is pitch? Pitch is the highness or lowness of a sound. It is determined by the number of vibrations made per second by a sounding body. The most accurate measurement of pitch is made by complex, electrically operated devices.

Have you wondered how a siren produces its sound? The siren disk is made of metal and notched on the rim. A strip of metal is held against the notches as the disk rotates. The faster the wheel is rotated, the shriller becomes the sound. The familiar siren effect is produced by varying the speed of the disk. We can also use a disk in which regularly spaced holes are punched to produce the major chord—the do-mi-sol-do you learn in singing. By counting the number of holes in the disk, we discover that there is a definite relation be-

The siren disk is rotated at varying speeds. A stiff card is held against the holes or the notched edge to produce sound. In fire sirens a blast of air is blown through the holes to produce sound.

tween one tone and another tone.

We can ordinarily hear vibrations ranging from about 16 per second to somewhat more than 20,000 per second.

There are two systems of figuring pitch. One is the musician's scale, which is based upon an *A* of 440 vibrations per second; the other is the scientist's scale, based upon a middle *C* of 256 vibrations per second. Practically, the difference in scales is slight, but any device in tune on one system would be out-of-tune with instruments tuned with the other. The musician's middle *C* is slightly higher than the scientist's middle *C*, being not quite eight vibrations per second more.

What is music? There are various ways of defining music, but probably the most accurate is to describe it as tones which are caused by vibration at regular intervals in combinations which have a certain mathematical relation to each other.

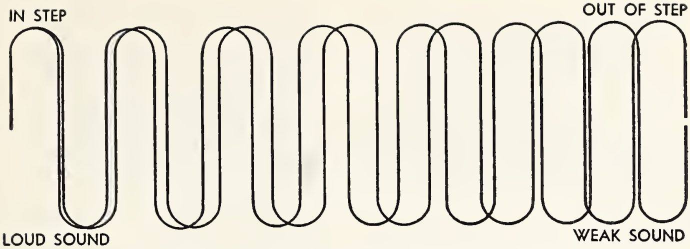
A series of holes punched at regular intervals in a uniformly rotating disk produce a musical tone, while a series of holes punched at irregular intervals produce a rasping noise. The regularity and harmony of vibration is basic to music. The fact that some popular music violates this principle accounts for its short life.

When two vibrating bars are placed together, almost in tune, the sound alternately increases and fades in volume. If the bars are tuned at an interval of two vibrations per second apart, there are two loud and two weak sounds per second. The waves of the sound, when they are out-of-step, push on the air molecules in opposite ways, and the sound is diminished as the molecules stand still. When the two waves are in step, both push the molecules in the same direction, increasing the loudness of the sounds. Thus you see that one sound can offset another, and the combined effect of two such sound waves is silence.

What determines pitch? When we wish to produce sounds of different pitch on the piano, we strike different keys. The keys cause hammers to strike wires inside the piano. If we look at the action of the piano and observe what wires are struck, we learn that the shorter, thinner wires produce the higher-pitched tones, while the longer, thicker wires produce the lower-pitched tones. To produce tones of different pitch on a violin or guitar, we move our fingers to change the length of the strings.

To tune a stringed instrument, we tighten or loosen the strings. If we tighten a string, we make it higher pitched; but if we loosen the string, we lower the pitch.

The pitch of the tone of a horn is produced in part by the vibration of the lips or the reed and in part by the length of the tube through which the sound passes. Xylophone [zī′lō·fōn] bars are tuned in the same way that strings are, the longer bars having the lower tones. The lowest-pitched pipes of a pipe organ



Sound waves may make each other stronger, or they may interfere with each other. Waves "in step" add their energy together, while waves "out of step" oppose each other.

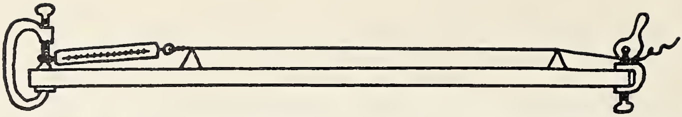
are large enough to use for culverts, while the smallest, highest-pitched pipes are the size of a lead pencil.

In addition to the fundamental tone, other tones are sometimes produced by the vibrating body. If a string vibrates as a whole, it may also vibrate to a smaller extent in two parts, producing two tones at one time. These overtones give music much of its pleasing quality. A tuning fork produces a purer tone than does a violin, but the tone is less pleasing.

High-frequency sound waves have some unusual uses. Milk which has been treated with sound waves of high frequency forms smaller curds than does ordinary milk. Sound waves have been used experimentally to cause smoke to settle in chimneys. A glass tube may be vibrated so rapidly by sound waves that if the skin touches it, a burn appears, although the tube is cold.

What are the various types of musical instruments? The types of musical instruments commonly used in the orchestra and band are of three classes: percussion [pẽr·kŭsh′*ŭ*n], stringed, and wind. The word "percussion" refers to striking. Drums, bells, triangles, cymbals, and related instruments are played by striking. Each of these instruments usually produces only one tone. They are used for producing rhythm. The xylophone and other instruments made of tuned bars are used for playing a tune.

The stringed instruments are the violin, guitar, cello, piano, and other related instruments. These are played by striking, picking, or bowing the strings to set them into vibration. The musical saw must be considered to be a string of unusual shape. Stringed instruments consist of a sounding box in which air columns are echoed to give resonance [rĕz′ȯ·n*ă*ns, a resounding] and tone quality to the tones of the strings. If you wish to see the difference produced by the sound box, attach a violin string on a broomstick with screw eyes, and support the string on a bridge. Ask someone to play a tune on it,



This device is used in the experiment to produce sounds of different pitch by comparing strings of varying sizes, tightnesses, and lengths.

and note the strange, thin tone.

The wind instruments are either the brass winds or wood winds. The trumpet, French horn, and trombone are brass instruments. The clarinet, flute, and bassoon are wood-wind instruments. In playing the horns, such as trumpets or trombones, the lips are vibrated by blowing as if you wish to blow a feather from your lip. The reed instruments, like the clarinet, are played by causing a wooden reed to vibrate by blowing into the mouthpiece.

DEMONSTRATION: HOW ARE MUSICAL TONES PRODUCED?

What to use: Wire string, sonometer or board with screw eyes or board, C-clamps, Stone tension clamp, spring balance—to 24 pounds, adjustable tuning fork.

What to do: How you do this demonstration depends upon the equipment available. The drawing shows how the clamps are used with the spring balance. Tighten the string, and place the bridges as shown. Pluck the string. Move the bridges closer together, and again pluck the string. Repeat several times. Then change the tightness of the string. Compare the various combinations.

Sound the adjustable tuning fork; make the sound audible in the room by holding the fork on a cigar box, and then repeat after adjusting the fork to produce another tone.

What was observed: Sketch the apparatus you used. Establish three rules which determine the pitch of a string.

What was learned: How are musical tones of differing pitch produced?

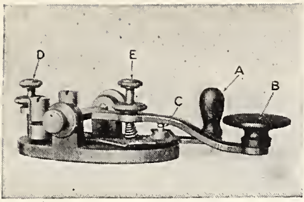
Exercise

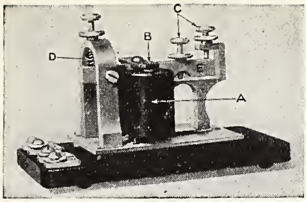
Complete these sentences:

A musical tone is pleasing because the vibrations are at —1— intervals. The scientific scale is based upon a middle *C* of —2— vibrations per second, the musical scale upon an *A* of —3— vibrations per second. The smallest number of vibrations that can be heard is —4— per second, the largest number —5—. The pitch of any object is determined by the number of —6— per second. Tones of strings may be changed by changing the —7— or —8— or by using strings of differing —9—. The drum is a —10— instrument, the trumpet a —11— instrument, and the violin a —12— instrument.

3. How do we communicate by telegraph?

The telegraph is not used directly by as many people as are the telephone or radio, yet indirectly it affects our lives in many





The parts indicated on the telegraph key, to the left, are the switch (**A**), the lever (**B**), contacts (**C**), and setscrews (**D** and **E**). On the telegraph sounder (*right*), **A** is the coil; **B** is the armature; **C** indicates the setscrew; **D**, the spring; and **E**, the sounder bar.

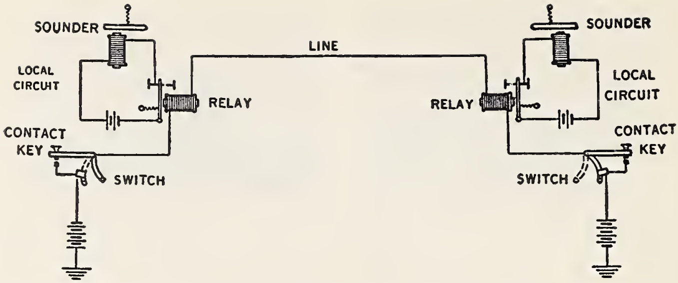
ways. The telegraph plays a very important part in issuing daily newspapers, both in sending messages for stories and for sending pictures. It is necessary for operation of railroad trains. The businessman uses the telegraph when he wishes to have an order filled quickly. It is possible to use the telegraph to have a stenographer in one city type out letters that may be read immediately in another city.

Although there were telegraph instruments before 1844, the successful magnetic telegraph was patented by Samuel Morse in that year. A British system had been in use for some time before this date, but it was operated on a different principle.

The first commercial line extended from Washington to Baltimore. At present there are about a quarter of a million miles of line and nearly two million miles of wire in use. The first Atlantic cable was laid in 1857. Now cables cross every ocean. The average person in the United States receives more than two telegrams a year.

How does the telegraph work? In its simplest form, the telegraph consists of three parts: the key, the sounder, and a battery with connecting wires. The connection between towns is a single wire, the return current necessary to make a complete circuit being carried by the ground. To make a ground connection, a piece of metal is sunk deep into the earth in contact with moist soil.

The sender is really a simple electric switch which is used to open and close a circuit. It is similar to a push button or knife switch. The kind of key shown in the diagram is the simplest and easiest to understand. However, it causes a jolt when pressed down, and to avoid this jolt the commercial key is made to be pushed sidewise. The second part of the sender is the switch. When the operator wishes to send a message, he opens the switch; when he has finished, he closes the switch. When the switch of the receiving set is closed, the only break in the circuit is at the sending station, and it may be closed by pressing down on the key. If the switch is open at the



The current flowing through a telegraph line is not strong enough to operate a sounder. Instead, the current is used to operate a sensitive switch called a relay which, in turn, operates a second circuit of which the sounder electromagnet is a part.

receiving station, it is impossible to make a complete circuit.

The receiver, or sounder, as the name suggests, is the instrument by means of which sounds used in sending messages are made. It consists of an electromagnet with an iron armature across its poles. When the key is closed and a current passes through the sounder, the electromagnet pulls down the armature. The armature strikes against a piece of metal, making a sharp click. When the connection is broken at the key, the electromagnet ceases to hold the armature, which is then pulled back by a spring to which it is attached. When the armature flies back, it strikes a second piece of metal, making another click. These two clicks make up the dot, if the interval between is short, or the dash, if the interval is long.

Why is code used? For each letter of the alphabet, a code of dots and dashes has been arranged. There are two codes: the Morse and the International. The latter is more widely used. The letter A is represented by a dot and a dash, thus: ·—. The letter G is represented by ——·. Expert telegraphers learn to read these signals by ear. The code is also printed on paper by a roller wheel over which a strip of paper passes. The wheel is pressed against the paper when current is flowing. The wheel dips in ink and prints dots and dashes on paper.

Only a small percentage of messages are sent by code today. Sports-writers sometimes carry portable sets and send by code, and code is used in smaller stations and towns for railroad business. The code, made by a buzzer, is widely used by radio amateurs.

What is a relay? The simple telegraph just described will not work for long distances because the current is not strong enough to operate the sounder. The relay

uses a weak current from the main line to control a stronger current which operates the telegraph set. The relay is really a very lightweight switch operated by an electromagnet. It consists of an electromagnet and an armature. When a current flows through the main line, it opens the circuit of the local sounder by attracting the armature of the relay through use of magnetism. When the main-line current stops, the local circuit is closed again, producing the second click. The relay has four binding posts, two of which connect with the main line and two with the local circuit. The diagram on page 476 shows how the connections are made.

Why is a closed circuit used? The telegraph system is operated on a closed circuit, because the wet cell loses its strength unless it is producing a current. Dry cells are not used in telegraphy.

What is multiplex telegraphy? The use of a wire for a single message at a time is extremely wasteful. Systems were early devised to send two messages over the same wire at a time, and at present a large number of messages may be sent at one time. The machinery of multiplex systems is complex, but it operates on a principle you can understand.

You know that one tuning fork will cause another of the same rate of vibration to be set in motion. Similarly, electric currents may be used to set a second object into vibration in tune with the first. Pairs of sending and receiving devices are so tuned that only one current frequency will cause them to work

Western Union Telegraph Company

Telegrams are transmitted over long distances by the multiplex system, which permits sending eight telegrams over a wire at one time. This operator is sending a message by multiplex.

Western Union Telegraph Company

A telegram is received on the multiplex system on a paper tape and pasted on the telegram blank as shown here.

together. Several currents of different frequency may pass over a wire at the same time and be separated out by the devices which receive the message.

What are the teletype and automatic printing devices? In most of the large telegraph offices of the United States, the message is typed on a typewriter keyboard, and the message comes out at the other end of the wire from another typewriter, typed upon a strip of paper. The strip of paper is pasted upon a telegraph form, and the telegram is ready.

It is possible to set type by telegraph. A single linotype [a typesetting machine] operator can set the type for any number of newspapers. This is done only on certain material that is desired in all cities, for local news that is interesting in one city might have little appeal in another. For stories of national importance the device permits saving of time.

The most important work of telegraphy is to carry messages quickly and to permit transmitting printed or typed material just as it is written. There are devices by which even handwriting may be sent by telegraph, making it possible for a document requiring a signature to be sent by wire.

DEMONSTRATION: HOW DOES THE TELEGRAPH WORK?

What to use: Simple demonstration telegraph set, wire, and cells.

What to do: Set up keys and two sounders, and practice sending code. Observe how the instruments are adjusted to make two clicks. Study the wiring until you can draw a diagram of it.

What was observed: Diagram the wiring of the key, cell, and sounder.

What was learned: On what principle of electricity does the telegraph instrument depend?

Exercise

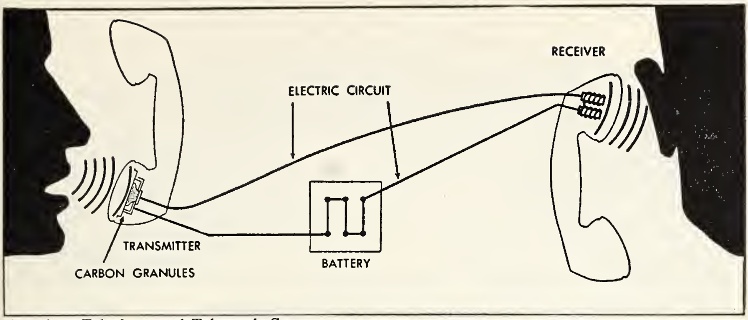
Complete these sentences:

When the telegraph —1— is pressed down, a circuit is completed, and current flowing through an —2— attracts an iron —3—, causing a click. When the key is released, the coils lose their —4—, and a —5— pulls back the armature, causing a second click. A short time between clicks represents a —6—, a longer time a —7—. To make possible use of a weak main-line current, a —8— is used. Telegraph circuits are kept —9—.

4. How does the telephone work?

Of all the inventions of the last century, few have become more a part of the everyday life of the people of the United States than has the telephone. More than half the telephones in the world are in the United States.

The telephone was invented in 1876, more or less accidentally, by Alexander Graham Bell while he was working on a telegraph set that would carry music. The first public telephone was installed in 1877 in Massachusetts.



American Telephone and Telegraph Company

In its simplest form the telephone is a circuit provided with a device which controls the strength of a current flowing to an electromagnet.

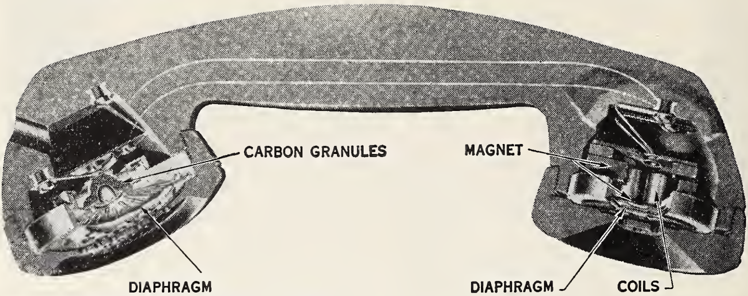
By the end of the first year 776 telephones were in use. Today the use of the telephone is so extensive that one can talk by telephone to almost any person in the United States or in any large city in the world. There are now about 35 million telephones in the United States—or about as many as the number of registered automobiles.

It is estimated that there are about 72 million telephone conversations a day. To connect these telephones, more than 70 million miles of wire are used.

What do telephone wires carry? Since you seem to hear voices over the telephone, you might imagine that the wires carry sound waves. Such is not the case. Because of the low speed of sound, it could not travel long distances fast enough to make conversation possible. To talk to a friend 10 miles away, you would have to wait 50 seconds for the sound waves to reach you and then wait 50 more seconds until your voice reached the other person. The telephone wires carry electricity, which travels with slightly less speed than does light. What you hear is the vibration of a piece of metal in the receiver.

What does the transmitter do? The sender of the telephone is called a transmitter. Its parts are the mouthpiece, which collects and concentrates sound waves; the disk, which is vibrated by sound waves; and the carbon particles in a small box. Connections are provided so that the current flows through the box.

When you speak into the transmitter, the sound waves set up by your voice cause the disk to vibrate. The disk is attached to the cover of the small box shown in the diagram, and the cover is moved back and forth in step with the sound waves. The cover of the box has no direct electrical connection with the box itself. The only way that current can flow through the box is by passing through the carbon grains.



American Telephone and Telegraph Company

Locate the essential parts of the telephone and read the text to learn what work each part does.

Current is carried through the box by wires attached to batteries.

As the cover of the box moves inward, the carbon particles are moved closer together. When they are close together, the resistance is decreased and there is a larger current. When the air waves permit the cover to move outward, the particles are farther apart and there is less current flowing through the box.

The object of the transmitter, then, is to change the strength of the current in proportion to the frequency and strength of the sound waves. The transmitter is a form of the rheostat, a device for changing resistance.

What does the receiver do? The receiver reproduces the sound waves that enter the transmitter. It consists of a permanent U-shaped magnet, with a coil of wire wound around each end to make an electromagnet. In front of the magnet is a soft iron disk, called a diaphragm. When the varying currents set up in the transmitter reach the receiver, they produce varying currents in the coils of the electromagnets. When a strong current passes through the wires, the electromagnet pulls the diaphragm through a greater distance than when a weaker current passes through. Thus the diaphragm of the receiver is made to vibrate by the electromagnet at exactly the same rate that the transmitter diaphragm is vibrated by the voice. The vibrations of the diaphragm set the air in motion inside the receiver, producing sound waves. Each telephone has a transmitter and receiver, which we use alternately. The first telephones combined the two. It is possible to wire telephone receivers in such a way that for short distances they may be used as transmitters.

How do currents cover long distances? We know that sound does not travel far. The electric current that we study in the laboratory soon loses its strength when it encounters resistance in

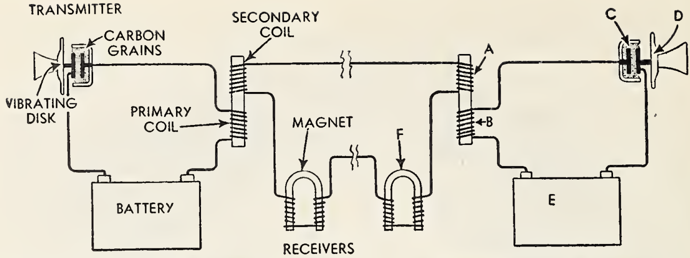
American Telephone and Telegraph Company

This is a drawing of the standard dial telephone. Locate and name as many parts as you can.

wires, and the current does not travel far, either.

There are several ways of making currents travel long distances. One is by the use of the induction coil. Instead of the current from the transmitter being carried through the wires directly, it is first sent through the primary coil of an induction coil. An induced current of much higher voltage travels over the wire, and as a result less of the current is lost as heat energy.

A second way of increasing the strength of currents is to use radio tubes as relays. A very weak current entering the tube is used to control a much stronger current in another circuit. These amplifiers are used in all long-distance communication.



This diagram shows the essential parts of a complete telephone system. With the help of the text, trace energy from the sound waves striking the vibrating disk through to the receivers. Match the letters on one half the drawing with the words on the other half.

What does Central do? Each telephone in a system may be connected to any other telephone by connections made at the central telephone exchange. The wires from each telephone end in a plug connection. To connect any two lines, a cord is plugged into each of the connections, completing the circuit. The cords are handled by Central.

In most large-city systems, the Central is completely automatic. The series of numbers is dialed by turning a disk in which holes are cut. To dial 9, the disk turns more than half a revolution; to dial 2, the disk turns a short distance. The dial clicks a connection which operates a complex series of electromagnets. These electromagnets in the central exchange make the desired connection. From this you can see that the dial system is extremely complex in its operation.

DEMONSTRATION: HOW ARE SOUND WAVES PRODUCED BY TELEPHONES?

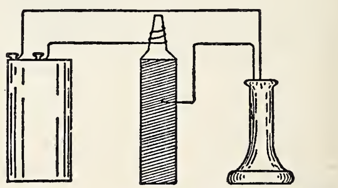
What to use: Telephone receiver, wires, dry cell, file, induction coil.

What to do: Connect the apparatus as shown in the diagram. Draw the loose connection across the file, listening to the sound in the receiver.

Connect the cell to the primary of the induction coil and the telephone receiver to the secondary.

What was observed: Describe the sounds caused by each of the parts of the demonstration.

What was learned: How do you know that sound can be produced by electric currents?



Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: transmitter, carbon grains, resistance, metal disk, sound waves, electromagnet, varying current, vibrate, conducts electricity, permanent magnet, soft iron.

5. What is electronic communication?

We live today in a world which broadens the meaning of communication to include the making and sending of pictures as events occur, seeing in the dark, and exploring the invisible. These apparently magical feats are possible because of electronic tubes.

What is the science of electronics? Electrons are both the smallest particles of matter and the smallest electrical charges. Three billion billion billion (3×10^{27}) of them would weigh about an ounce. They are always negative charges of electricity.

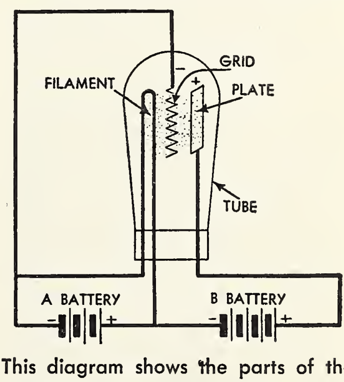
Electronics is the branch of science which uses free electrons to do useful work. Since the beginnings of the earth free electrons have discharged through the air in the form of lightning. Whenever a storm cloud with more electrons than it needs approaches one with less than it needs to be in balance, electrons jump the gap between them.

In order to control the flow of electrons with great accuracy, the electrons are passed through a glass tube from which most of the gas is removed. Edison discovered, when making his lamp, that the filament gave off charged particles which blackened the glass. In attempting to collect these particles, he placed a positively charged metal plate in the tube. He discovered that a small current flowed from the filament to the metal plate. At about the same time others were experimenting with producing X rays in vacuum tubes.

Some of the chief branches of electronics today relate to radio and television, X rays, the electron microscope, movies, and carrying of electric power.

How may vacuum tubes control currents? One of the important uses of vacuum tubes is to control the direction of flow of current. Most of our house currents are alternating, and yet alternating currents will not operate some parts of radios nor charge batteries. A man named Fleming tried to use the Edison tube in communication but it did not work. In 1906 De Forest added a wire screen, called a grid, between the filament and plate to control the flow of electrons.

This electron tube consists of three parts. When the filament is



This diagram shows the parts of the radio tube, and how they are connected to batteries. The dots represent a flow of electrons from the filament to the plate.

hot, as are the wires in a lamp, electrons are boiled out and thrown off. These free electrons are attracted by a plate which is kept positively charged by connecting it to a battery or generator. The flow of electrons from the filament to the plate is a direct current, for electrons cannot flow back from plate to filament. If an alternating current flows into the tube, that part which is going the wrong way merely is shut off.

Now let us review your knowledge of electricity. An electron has a negative electrical charge. Since unlike charges attract, a free electron can be attracted by any positively charged body or object. How much it is attracted depends upon the strength of the positive charge. A slight sidewise pull may only bend the path of the moving electron. A strong charge may cause the positively charged body to attract and capture the electron.

A negative charge will repel a moving electron. A small charge may bend the path of the electron away from the negative charge. A strong negative charge may turn back the free electron.

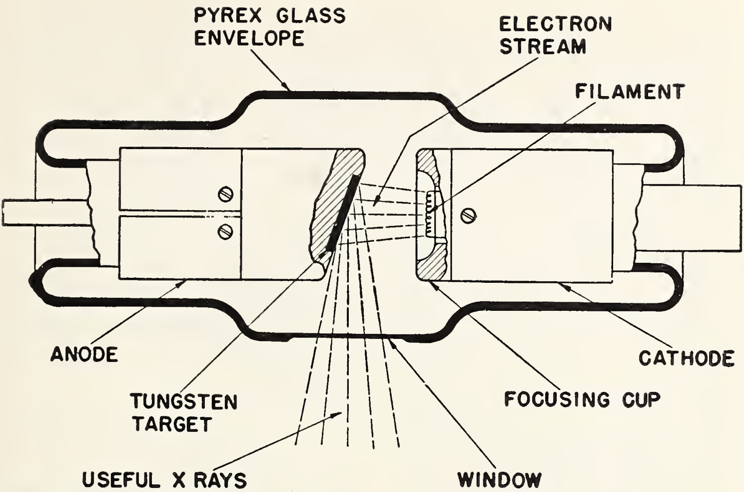
In order to control the amount of direct current which flows from the tube, the grid may be given an electrical charge. With just the right amount of negative charge, the grid can repel the electrons so that they cannot get past it to the plate. When the grid has no charge the electrons pass through it to the plate, producing a current. A small positive charge on the grid speeds the flow of electrons. Thus by giving the grid varying electrical charges part of the time, and giving it none at others the amount of current flowing through the tube may be regulated. This tube is the most important of electronic tubes, for it is the common radio tube. It also is used to control currents used in most other electronic devices.

What is a transistor tube? A newer type of electronic tube called the transistor is entirely different from the ordinary radio tube. It consists of a small crystal of the metallic element germanium attached to a metal base, and two circuits.

A transistor tube may be made smaller than a pencil eraser, uses less current than a radio tube, is simpler to build than a radio tube, and does not require warming up. It does the same work as a radio tube.

Radio or electronic tubes do four things. They change alternating to direct current. They amplify or build up the strength of a current. They change continuous waves to interrupted or pulsating waves. They may produce waves which change direction with a regular, controlled frequency.

How do electron tubes produce waves? In the world of electronics there are many kinds of electric waves, more accurately called electromagnetic radiations. The common transformer, you remember, operates because a magnetic wave passes from one



General Electric X-ray Corporation

The cathode of this X-ray tube has a high-voltage negative charge. Electrons from the hot filament are attracted to the positively charged anode.

coil or wire to another. These waves move very fast, at the speed of light, but a considerable time may pass between waves. The first wave travels a considerable distance before the next one starts. Because this distance is great, we say that ordinary electromagnetic waves have very long wave length. Traveling at a speed of light, 186,000 miles per second, and with a frequency or rate of change of 120 times per second, the wave length, or distance between transformer waves, is 1550 miles ($186,000 \div 120 = 1550$).

When 10,000 of these magnetic waves pass a given point per second, we have radio waves. These are long waves being 18.6 miles apart. The shortest radio waves are less than an inch in length. Next come infrared or heat waves, which have a wave length less than that of the shortest radio waves. Then come light, ultraviolet radiation, X rays, gamma rays, and finally the shortest of all, the cosmic rays.

Electron tubes can be used to produce any of these radiations or wave lengths except perhaps cosmic rays.

You know that when an electron changes its rate of movement, or starts to move from being still, its magnetic field moves with it. A moving magnetic field is a single electromagnetic wave. You produce such a magnetic radiation or wave when you lift a magnet. Electronic radiations may be produced at almost any rate desired by electronic tubes because they can be used to change the direction or rate of movement of electrons.

How does the X ray work? Some tubes produce radiations in a different way. You know how the fluorescent lamp is caused to glow by causing radiations to strike the paint inside the tube. The fluorescent lamp is an electronic tube.

Somewhat similar to this lamp is the X-ray tube. This tube has a filament and plate, but no grid. It carries a current at a very high voltage, so that the electrons shoot from the filament to the plate, which is called a target, with tremendous force. When the electrons strike the target, they give off X rays. These rays are invisible, and will pass through almost any common material. Some materials, such as cloth and flesh, permit them to pass through readily. Others, such as bones and metals, do not permit the X rays to pass through so readily. Thus when X rays strike the hand the bones produce an invisible shadow.

To make the shadow visible, a screen of fluorescent material is placed behind the hand. Where the X rays strike the screen it glows with a soft light. Where the X rays are partially cut off by the bones, no light is produced. The bones of the hand are shown as a shadow. This shadow may be studied or photographed to examine the condition of the bones. By producing X rays of different strength almost any object may be examined, so that we can see what is inside it. X rays also may be used to take pictures directly, for when they fall on a film they will expose it just as light does.

Exercise

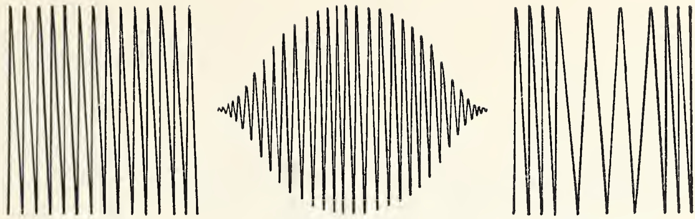
Complete these sentences:

The study and use of free electrons is the science of —1—. In a radio tube electrons are given off by the —2— and are attracted to the —3—, causing a —4— to flow through the tube. The strength of this current is controlled by adding and charging a —5—. All electromagnetic radiations or waves travel at the speed of —6— miles per second. The distance between waves is called —7—. The longest waves are —8— waves, the shortest —9— rays. A material which glows when struck by certain rays or by electrons is said to be —10—.

6. How are radio messages sent?

Radio messages were first sent only as telegraph code which produced a buzzing noise in a receiver. Now they are sent so clearly and so well that some people actually think they are listening to some person or band instead of to a radio.

Radio includes many things—commercial broadcasting, relaying telephone calls over land and ocean, handy talking phones, communication between ground and plane, devices for detecting invisible objects, sending pictures, television, collecting weather information, and cooking and heating without fire. All



The generated wave is a powerful alternating current. It does not vary in strength, nor does the interval between waves vary. A wave may be modulated, or changed, in strength as in amplitude modulation; or the interval between alterations of the current may vary as in frequency modulation.

these devices and many others depend upon producing radio waves of different lengths, controlling them as desired, and sending them through space in the right direction.

How do radio waves travel? All radio waves travel in straight lines. Very short waves travel very much as light does, and are soon lost into space. But longer radio waves are reflected to the earth from a layer of heavily charged upper air. Thus it is possible to use the longer waves to broadcast around the world.

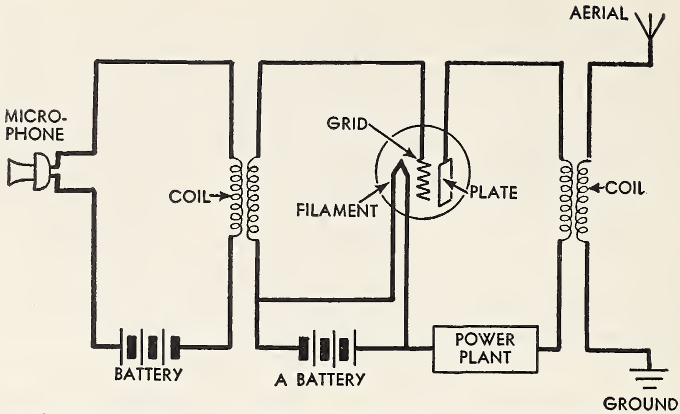
Because radio is worked out by scientists, all measurement of waves is done in the metric system.

Radio waves travel at the same speed as light waves, 300,000 kilometers per second. If the wave length is 300 meters (about 1000 feet), the frequency is 1000 kilocycles, or one million complete changes per second. This wave length and frequency are typical of ordinary broadcast waves. Short waves have higher frequencies.

Sound waves are slow. Only 100 to 8000 vocal sound waves pass a given point per second. An important problem in broadcasting is to combine the slow sound waves with the fast radio waves so that the radio waves carry sound. If 250 sound waves pass a point at the same time that a million radio waves pass the same point, it is necessary for each sound wave to be carried by 4000 radio waves. ($1{,}000{,}000 \div 250 = 4000$.)

What does the radio tube do? Radio tubes do four things. They set up magnetic waves having the same frequency as the sound waves. They change alternating to direct current. They make possible the control of a large current with a small current. They control amount of current flowing through the tube. To understand how they do this, we must recall the parts of a radio tube.

The central part of the radio tube is the hot filament. It is connected in a circuit to two batteries or other current supply. One circuit, the A-battery cir-



The radio transmitter is much more complex than this simple diagram, which shows only the essential steps in changing sound waves to radio waves. Study the diagram with the aid of the text.

cuit, merely heats it. In the other circuit, the B-battery circuit, the filament is connected to the negative side of the circuit, the plate to the positive side (p. 483).

The grid is between the filament and plate and may be connected to the negative side of the circuit. Consequently, its charge is then always negative. The strength of this negative charge varies. When it is strongly negative, it repels the electrons to such an extent that they cannot reach the plate. When the grid charge is weakly negative, it repels the electrons enough to prevent them from sticking to the wires of the screen as they slip through the spaces to the plate. The grid serves as a gate or valve to control the flow of electrons.

What does the radio broadcasting station do? The broadcasting station, whether it be a telephone on a train or the great studio ready for a nationwide broadcast, has one job to do. That is to send out radio waves which vary in proportion to the sound waves entering the microphone. Sound waves are used to control the current which produces the broadcast waves.

A telephone transmitter was the first microphone and still may be used. It controls the current which flows through it and into the grid. The current from the microphone does not flow directly to the grid, but through the primary coil of an induction coil. This coil sends magnetic waves through the secondary coil which in turn controls the grid. The circuit is so arranged that a strong sound wave permits a strong current to flow through the radio while a weak sound wave reduces the current.

Since the sound controls the strength of waves flowing through the tube, the electric waves are said to be modulated

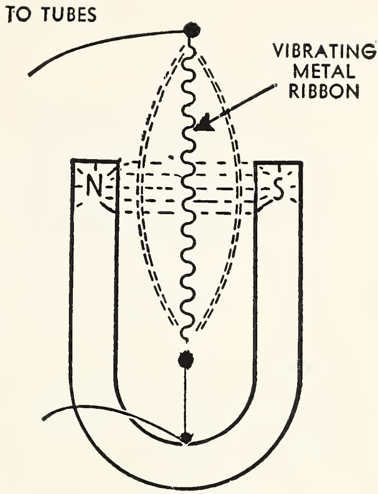
by the sound. The electric waves may be changed in strength in two ways. In amplitude modulation [the old-fashioned AM] the magnetic waves are made stronger or weaker. In frequency modulation [FM] the current is made stronger or weaker by producing more or fewer waves all of the same strength in a given time.

However the strength of the current through the tube is controlled, it flows from filament to plate through coils connected to an aerial. The secondary of the aerial coil steps up the voltage greatly, sending electrons with great force through the aerial. These moving electrons send a magnetic field out into space in the form of radio waves.

Although broadcasters say the show is on the air it really is not. It is traveling through space at the speed of light and would broadcast better if there were no air to interfere.

Stray electrical radiations from transformers, fluorescent lamps, spark coils, electric razors, and other devices may become mixed with radio waves to form static. Lightening and electric charges in clouds and in the air may also cause static. You can make a crackling noise in the radio by shaking a lamp with the bulb screwed loosely. The shorter radio waves are much less subject to being mixed with static than are long waves, for most static is long wave.

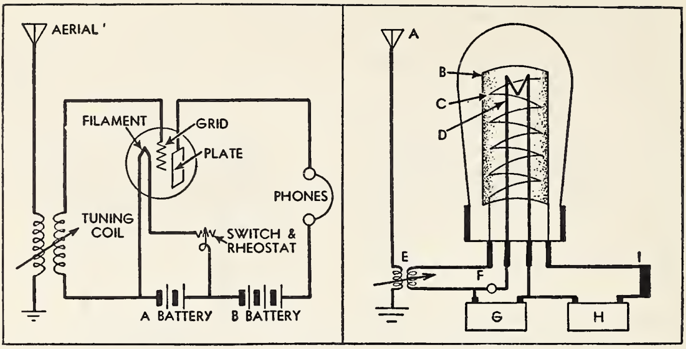
What does the microphone do? Early broadcasting was done with telephone transmitters, but today they are not sensitive enough for the many kinds of sound sent over the radio. One microphone now in use consists of two metal plates which are electrically charged and so arranged that the one in front is moved by the vibration of the sound waves. Vibration of one plate changes the strength of the charge in the other. This microphone contains a radio tube which makes the current stronger.



Sound waves cause a metal ribbon to vibrate, producing a current in the magnetic microphone.

Exercise

Copy the diagram of a sending station in your notebook, and label all the parts named in the text. Make your drawing exactly twice as large as the one shown. Use your ruler to make the lines straight and the measurements accurate.



The first diagram shows the parts of a radio receiver with the various parts named. The second diagram shows the same hookup drawn more like a picture and with the parts lettered. Match the letters and the names to be sure you understand the diagrams.

7. How does the radio receiving set work?

The process in the receiving set reverses to some extent the process of the sending set. A current comes into the aerial, is changed and increased in strength, operates a loud-speaker which is much like a telephone receiver, and produces sound waves.

Why use an aerial? The aerial collects the radio waves from the sending station. Magnetic radio waves travel from the sending aerial and cut through all conductors, producing very weak alternating currents in them. The current produced by broadcasting station's is largely wasted, and that which comes into the aerials of receiving sets is very weak indeed.

The current flows from the receiving aerial to the earth through a ground connection.

What does the radio receiving set consist of? A simple radio set may consist of one tube. The current from the aerial flows through an induction coil which is connected to the grid. The aerial current controls the charge of the grid, changing the strength of its negative charge.

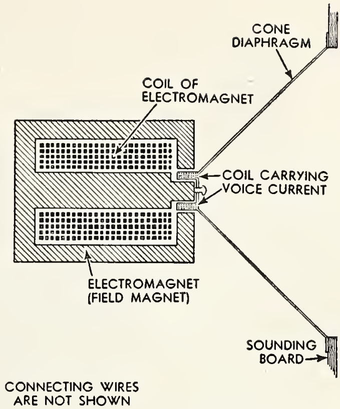
When no program is received, a steady current flows through the radio tube, which is essentially the same whether used for detecting the current or amplifying it or producing it. The same three parts are always connected in the same general way to the A and B circuits.

The current flowing through the radio tube, as it is controlled by the charges in the grid, flows through a telephone receiver or speaker and produces sound waves. The tube, and the condensers working with it, combine the many alternating current cy-

cles into a smoothed wave and change them to a direct current which will operate the magnet of the receiver or speaker.

The commercial or regular radio is different in many ways from the simple one-tube radio. It has many tubes, it does not have batteries, and it has a loud-speaker instead of a headphone. Current is supplied by use of a radio-type tube which changes the alternating 110-volt light current to direct current. This tube does nothing to bring in the program at all, except to supply the energy to operate the set. Various combinations of transformers, or coils, and coils of resistance wire provide currents of the strength needed in various parts of the radio.

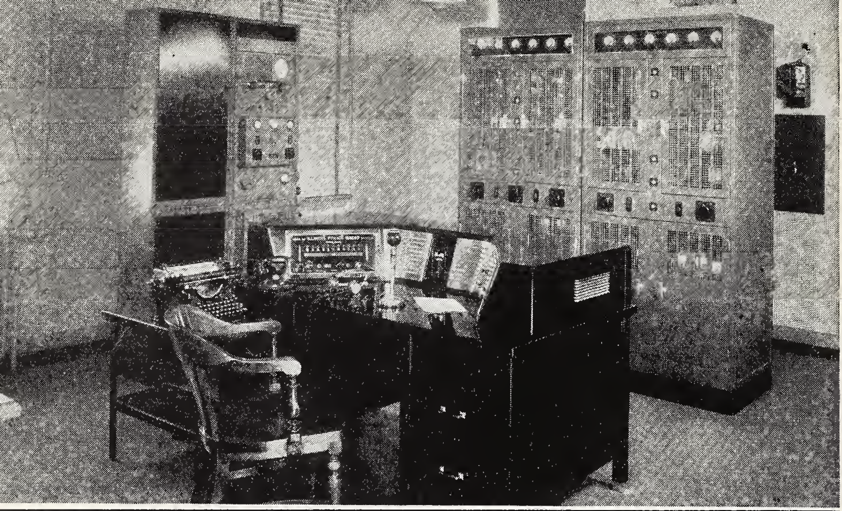
The first tube in a commercial radio is called an amplifier tube and is connected to the aerial to strengthen the energy of the transmitted radio waves enough that they will operate the other tubes. This tube is connected to the grid of a second tube which strengthens or amplifies the current flowing from the first tube. There may be several amplifier tubes, each controlled by the tube before it. In this way, the amount of current that flows through the radio may be greatly increased. With a one-tube set, the current from the aerial is so weak that it cannot control strong currents. By building up the strength of the current in several steps, it is possible to produce the loud sound waves needed for easy hearing.



This diagram of the dynamic loud-speaker shows only the essential parts. It consists of two electromagnets which repel and attract each other. The smaller electromagnet is attached to a cone which is vibrated to produce sound waves.

After the current is built up by the amplifying tubes, it goes through a second tube which changes the many radio waves into waves of the same frequency as sound waves but not actually sound waves. There frequently is an extra-large tube used to give power to the loud-speaker.

The principle of the loud-speaker is exactly the same as that of a telephone receiver. Instead, however, of using a soft iron plate to be attracted by the electromagnet, the electromagnet is mounted on the disk itself. A stronger repulsion and attraction between magnets is possible than between a magnet and unmagnetized iron. There are, in addition to the electromagnet on the disk, field magnets which are kept magnetized by a steady current



Western Electric Company

The use of radio in law enforcement is becoming increasingly important. The console in the foreground of the picture at the top contains the controls, and the cabinet in the background contains the transmitting apparatus of the Illinois State Police radio network. The radio-equipped squad car shown below is used in Nashville, Tennessee.

from a battery or the light socket. The disk is a cone made of a heavy paper. The moving coil, operated by current from the last radio tube, moves back and forth as the current changes, and the strength of the magnetic field changes. The disk vibrates, set-

ting up sound waves which travel through the air.

If the loud-speaker is mounted on a large piece of plywood, it gives low-pitched tones much superior to the tones obtained from mounting the speaker in a cabinet. Commercial radios, even the largest, are not large enough to contain sounding boards which reproduce all bass tones faithfully. Many of the higher-pitched tones are also lost by most radio speakers.

Why must we tune the radio? Each transmitting station is assigned a certain wave length and required by law to do all its broadcasting on that wave length. The length of the transmitted waves is controlled by coils, condensers, and other devices.

Your home radio, on the other hand, will receive a large variety of wave lengths. If it is equipped for both long- and short-wave reception, you can receive waves varying from a few inches up to more than a mile in length. The rate at which the current flows back and forth through the tubes of your radio is also controlled by coils and condensers.

You know that if two tuning forks of the same pitch are mounted together, striking the first will cause the second to vibrate. If they are not of the same pitch, or tuned, the second does not vibrate. Similarly, it is necessary to get the currents flowing through the tubes of your receiving set to alternate at the same rate the sending station currents alternate. When you have done so, by turning a knob which controls a coil or a condenser or both, your set is tuned.

What kind of set should you buy? Because most people enjoy radio, it is probably better to have any set than none at all. Even the poorest set, provided it works, brings in sounds that can be recognized as speech or music. Even moderately good radios are quite expensive.

Large radios are the only kind which can give faithful reproduction of the original sounds. The best table models, however, produce tones as good as those of poor quality console models. Portable and pocket radios give tones of very poor quality and are expensive to operate. In general, the smaller the radio the worse its performance may be expected to be.

Radio sales appeals are too often concentrated upon gadgets instead of improvement of radios. There are many devices that may be of some slight value—remote control, the electric tuning eye, short wave, and airplane dials. But these have no bearing at all upon the type of sound produced by the radio, which is the only thing of importance.

The radio to buy is the one that gives the best reproduction of the programs from the station to which you want to listen. No radio does everything well. Make up your mind what you want, and get it, paying no attention to nonessentials.

Exercise

Complete these sentences:

The radio tube consists of three parts. The —1— is a hot wire which gives off —2— when heated. The —3— is a screen which acts as a valve controlling the flow of —4— from the —5— to the plate. The —6— is always positively charged and attracts the —7—, which are charges of negative electricity. —8— charges repel. The current which flows through the aerial is produced when —9— cut through it. This current is used to control the charge of the —10—. The current which flows from the tube controls an —11— in the loud-speaker.

8. How is sound recorded?

When you go to the neighborhood movie and the sound of the singer's voice comes from the screen or the rifles crack as another villain bites the dust, you are not listening to voices or shots at all. What you are hearing is the sound of vibrating disks moved by electric currents.

Thomas A. Edison, Inc.

The modern dictating machine makes a record by use of electronic devices controlled by sound waves collected by the microphone. The record is played through head phones.

There are several types of sound recorders, among which are the phonograph record, the sound track on film, and the wire or tape recorder.

How are phonograph records made? The first phonograph records were made by talking into a horn causing the sound waves to vibrate a needle against a moving cylinder. The needle scratched a groove in the surface of the cylinder, which was usually of wax, and made a record of the sound waves. The cylinder was turned by a crank and moved along by a screw. Then the needle was moved back to the beginning, placed in the groove, and the needle was vibrated by the groove, setting the disk to which it was attached into motion and producing sound waves.

Records are made now by use of electricity. You might imagine a needle attached to the vibrating disk of the telephone receiver

being used to cut a groove in a record as it was vibrated. This is the general principle involved in making records.

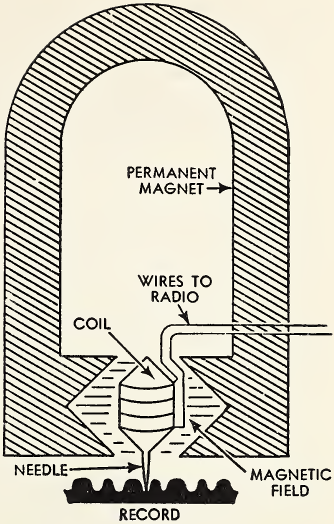
The record is made of smooth beeswax. The needle is mounted on an arm which is moved with a worm gear to make the grooves in the record the right distance apart. The wax record is mounted on a turntable which turns at an even speed.

When all is ready, the program or speech to be recorded is played or spoken into a microphone. The current from the microphone is amplified by radio tubes to make it strong enough to act through an electromagnet and vibrate the cutting needle. As the disk turns, the needle vibrates and cuts a groove that wavers from side to side in the soft wax. The wax shaving is picked up by a vacuum cleaner device to prevent it from sticking and spoiling the record. Two records are made at the same time.

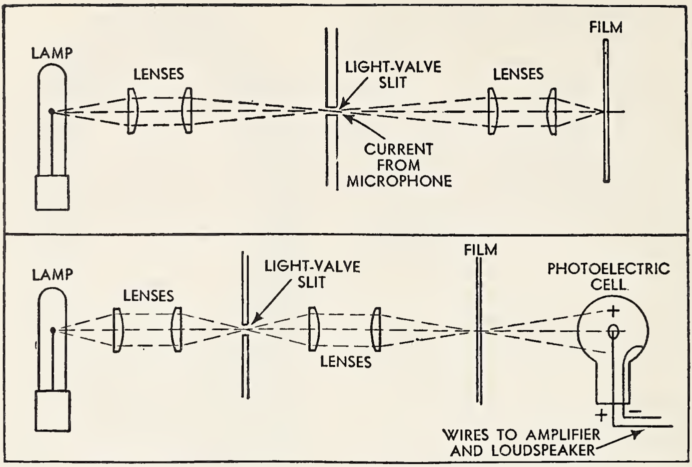
One record is played, and if it sounds all right it is melted down and used for wax. Playing a soft wax record spoils it for further use. The second record is covered with carbon and electroplated to make a metal master record. Other records are formed by pressing soft plastic or wax against the master record by a molding process.

In making dictaphone records and home recordings, only one record is made. It can be played only a few times before it is badly worn.

How are records played? The sound reproducer, called a pickup, is a generator of current. One kind consists of a horseshoe magnet, with the ends brought in toward the center. Inside the space between the ends of the magnet is a coil of wire, attached to connections to the loud-speaking equipment. The coil of wire has a core of metal, to which the needle is attached. When the needle is placed on the moving record, it vibrates. The vibrating needle causes the coil of wire to cut the magnetic field, producing a current. The current flows from the coil to the radio system which makes the loud-speaker



This phonograph pickup operates on the principle that when a conductor cuts a magnetic field, a current is produced. The coil is vibrated by the needle moving in the groove of the phonograph record.



Current from a microphone causes a beam of light to expose the film to make the sound track (*top*). The microphone current opens and closes the light-valve slit. The sound projector (*bottom*) causes a light to shine through the sound film onto a photoelectric cell which produces a current to operate a radio amplifier, connected to a loud-speaker behind the movie screen.

produce sound waves. The strength of the current flowing into the radio is in proportion to the sounds that caused the grooves to be cut on the record.

Another kind of pickup has the needle attached to a crystal through which a current is flowing. The resistance of this crystal changes as it is turned by the vibrating needle, and varies the current. The current from the pickup is fed into the radio.

Any radio may be made into a phonograph by adding a pickup and turntable, turned by a motor, and by connecting it properly to the radio. This connection takes the place of the aerial. There are many of the old-type mechanical phonographs available and in use for picnics, in cabins, and where there is no electric power available. These phonographs consist of a spring-driven motor, a turntable, a reproducer, and a horn. The spring is wound up, and the motor is started by releasing a brake. The record is placed on a turntable, which whirls around. The needle is attached to a disk in the reproducer, and the grooves of the record vibrate the needle and produce sound waves. The horn increases the volume and resonance of the sound. One can play a phonograph record with the sharp corner of a calling card.

When playing a phonograph, needles should be used only a few times, for a dull needle becomes rough and blunt, and scrapes away the sides of the grooves.

How do tape recorders work? You know that you can put a piece of steel inside a coil carrying a current, and magnetize the steel. A wire recorder works on the same principle. Sound waves are picked up by a microphone, and made to control a current flowing through a coil. A very hard steel wire is passed through the coil and is magnetized in proportion to the strength of the current.

When the wire is played, it is pulled through another coil by the playing machine. You are familiar with the experiment in which you move a magnet through a coil and produce a small current which can be made to move a galvanometer needle. The player employs this principle. The magnetized wire moving through the coil sets up a current which is fed into amplifier tubes of a radio speaker. The current controls the sound coming from the speaker.

The tape recorder works on the same principle, except that instead of a wire being used, a paper tape covered with iron oxide is substituted. You probably remember that the lodestone is a natural magnet made of iron oxide. The iron oxide on the tape is played in the same way that a wire is played.

Tape and wire recorders have several advantages. The materials used are fairly inexpensive, and a long program can be recorded on one spool or wire or tape. They do not require much room for storage. Both the wire and tape may be cleared by passing them through a uniform magnetic field, as often as desired. The best quality wire recorders and tape recorders are very expensive.

How is sound recorded on film? To record sound on film, the same setup of microphone and amplifier tubes is used that is used for recording the sound on a disk record.

As you know, to make a mark on film, light must shine on the film. To shine light on film, a light gate is used as shown in the diagram on page 496. A lamp gives off light, and lenses cause the light to shine through a slit onto the edge of the film. There is a magnet on either side of the slit. In front of the slit are two metal ribbons, weaker and thinner than a spider's web. The current from the microphone and amplifiers cause these ribbons to move together or apart, depending on the magnetic charge, thus exposing the film to varying amounts of light. The film moves along at constant speed. On the edge of the film the sound track is printed as a series of lines—some close together, some farther apart, some wide, some narrow. The slit through which the light shines, when not covered by the metal ribbons, is two-thousandths of an inch wide.

Another type of film recorder uses a swinging mirror instead of a slit. The current swings the mirror. This arrangement causes the sound track to be shaped like the teeth of a jagged saw.

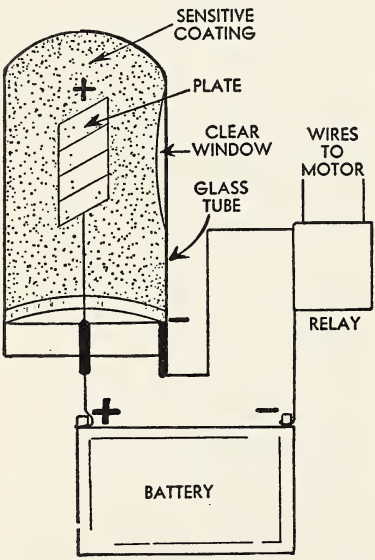
Exercise

Complete these sentences:

In making records, sound waves are picked up by a —1— which controls an electromagnet. The electromagnet moves a —2— back and forth, causing it to cut —3— in a revolving beeswax —4—. The disk is electroplated with —5— and used to make other records. The pickup contains a —6— and a coil which moves to produce a —7—, which is amplified and changed to sound by radio tubes. The film sound track is made by —8— passing through a slit and shining on the film. The size of the slit is controlled by the current from a —9—.

9. How do phototubes aid communication?

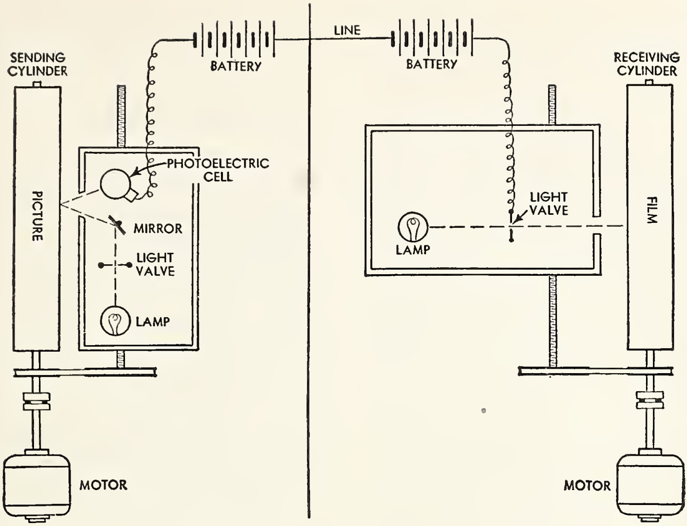
The photoelectric cell is familiar to us in the light meter used to measure room illumination and to estimate correct exposure for taking pictures. The photoelectric cell, as you recall, is a glass tube or plate covered with a chemical which gives off electrons when light shines on it, and a plate which collects the electrons. When the chemical and plate are connected, a current flows through the circuit.



This diagram shows how a phototube may be used to operate almost any device which can be controlled by a motor.

What is a phototube? A phototube is much like a photoelectric cell, except that it is used to carry a current rather than to generate one. The plate is connected to the positive pole of a current source, and the light-sensitive chemical to the negative pole. This arrangement increases the power of the plate to attract electrons and makes possible the use of a larger current. The current is still too small to do much except to give a charge to the grid of a radio-amplifier-type tube, however.

Substances which will give off electrons when light shines on them include sodium, potassium, lithium, selenium, caesium, and copper oxide. One of these light-sensitive materials is used to coat the inside of a curved glass tube. At the center of the tube the positive plate or rod is placed. The tube has a window of uncoated



The wired photo apparatus is used for carrying pictures over telegraph or telephone wires. The photograph is put on a revolving cylinder, and a reflected beam of light from the photograph controls the current in a photoelectric cell. The current controls a beam of light which prints a picture on the receiving set.

glass on the side opposite the light-sensitive material. Some phototubes contain gas, while others contain partial vacuums.

The number of electrons flowing from the light-sensitive chemical is in proportion to the brightness of light striking it. When the phototube is in the dark, no current flows at all.

How are pictures and prints sent by wire? Since the phototube has been perfected, many photographs used in newspapers are sent by wire. One system uses telegraph wires, while another uses telephone wires.

The photograph or printed material to be sent is fastened on a cylinder mounted on a long screw which is turned by a motor. A beam of light from a lamp shines through a light valve on a mirror and is directed on the picture. Where the picture is dark, little light is reflected from it. Where the picture is light, most of the light is reflected. These flashes of light reflect upon the photoelectric cell, which sends a current in proportion to the light received from the picture.

The motor of the receiving instrument is in step with that of the sending instrument. This motor turns the receiving cylinder, on which there is sensitive photographic film or paper. The current from the photoelectric cell, strengthened by batteries, comes over the wire and opens and closes a light valve through

which the light shines upon the sensitive film. If the valve opens wide from a strong current, the spot on the negative is strongly exposed; but if the current is weak, the valve opens slightly, and the spot on the film is only slightly exposed. The sensitive film is developed and printed as any other film is.

Pictures are similarly sent by radio, except that the current is used to operate the circuits in a radio instead of being sent by wire.

A method somewhat similar to the one just described is used to print newspapers by radio, and to send important documents rapidly. It is called facsimile. The process prints without the use of photographic film or paper, substituting instead one of several methods of using carbon paper or ink to make the impression.

How is sound taken from film? If you look at the sound system of your school motion-picture projector, you will not be able to see the phototube without taking the machine apart. This tube is located in a casing in the dark. Inside this casing there is also a small lamp with a lens system which concentrates the beam of light on the phototube (p. 496.).

The sound track of the motion picture film runs through a slit between the lamp and the phototube. The dark lines shut off the light, and reduce or turn off the current flowing from the phototube. When the clear film passes in front of the light beam, a stronger current flows. Since the marks on the sound track duplicate the pattern of the original sound waves, the current flowing from the phototube is in proportion to the strength and frequency of these sound waves. The current from the phototube controls the grid of a radio tube, which in turn feeds current to other tubes and to the speaker. With proper connections an ordinary radio can be used for a speaker for a sound motion-picture projector.

The sound track is recorded 19 frames ahead of the picture, and is run smoothly through the machine instead of in a series of jerks as is the case with the frames of the picture.

The speaker used in theaters is much larger than the home radio speaker. It generally has two or more sections. One section may reproduce the bass tones while the other may emphasize the higher-pitched tones. This speaker is mounted behind the screen to make the sound come from that direction.

Exercise

Draw a diagram of the phototube in your notebook.

Complete these sentences:

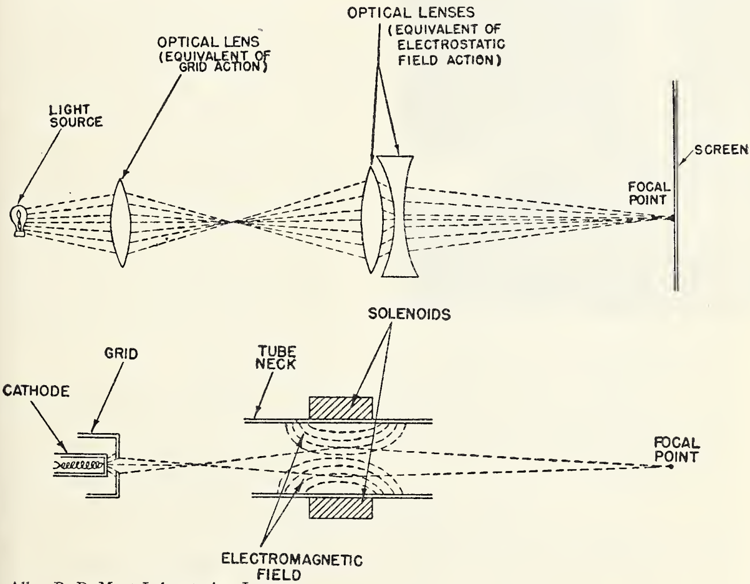
The light-sensitive material in a phototube gives off —1— which are attracted to a —2— charged plate when —3— enters the tube. In sending photographs by wire light is reflected from the picture to a —4— and the current passes over a wire to the receiver. In the receiver the current controls a —5— which admits light to a

photographic film. Light passing through a film sound track falls upon a —6— which produces a current which controls a radio system. Current from the radio system goes to the —7—.

10. How does television work?

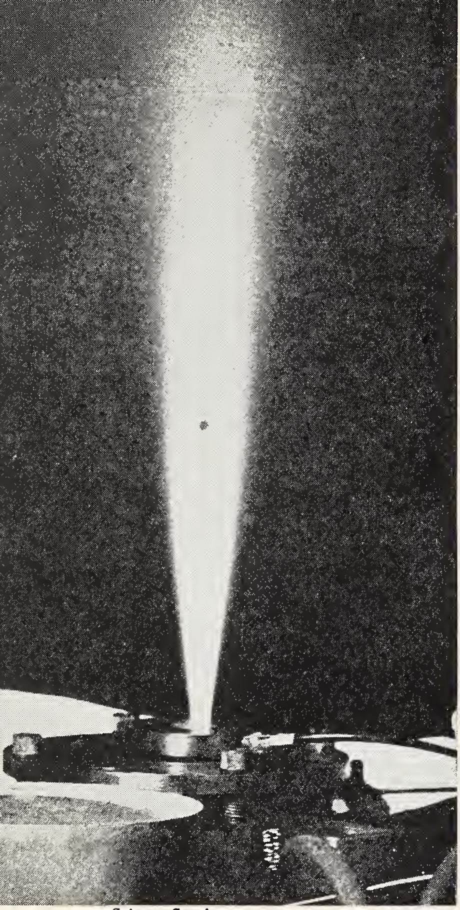
The use of electrons to communicate ideas is not so difficult in principle as it is in application. We have learned that we can free electrons from the atoms of which they are a part by use of heat, light, chemical action, or magnetic waves. We direct these free electrons so that they produce a current, and we can cause this current to do work of different kinds. Television is not based on new principles but applies old principles in complex ways.

What is an electron gun? An electron gun shoots a narrow beam of electrons through the space inside a glass vacuum tube (p. 504). The electrons are freed from a hot filament which is placed inside a metal cylinder with a small hole in the center of one end. This hole is the only opening through which the electrons can escape. To concentrate the beam of electrons escaping from the hole still more, metal disks also containing holes in



Allen B. DuMont Laboratories, Inc.

We are familiar with the method of controlling and focusing light rays. An electron beam from the hot filament of the cathode may be directed and focused by a magnetic field. This principle is applied in the electron microscope and in television devices.



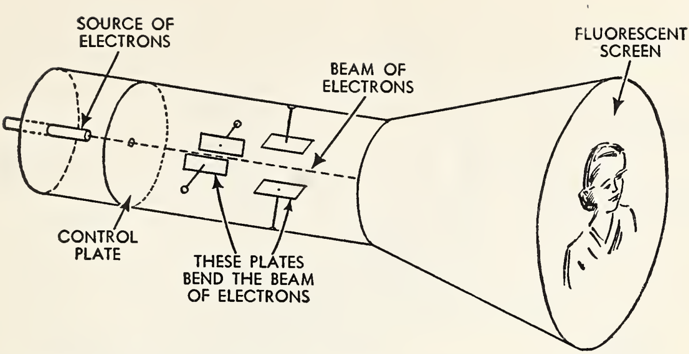
Science Service

Although electrons are invisible, they cause gases to give off light under certain conditions. This photograph shows the discharge of electrons from an electron gun.

their center are placed in line with the first hole. These disks are connected to a current so that they have a positive charge, which attracts and speeds up the electrons. The last disk of the series controlling the beam of electrons may have a charge of several thousand volts. This strong voltage causes the electrons to be accelerated so that they move with great force from the electron gun.

This beam of electrons can be controlled in two ways; in strength and in direction. The strength of the beam may be controlled by a grid, somewhat like that of a radio tube. This grid is placed at the opening of the cylinder containing the filament. When it is given a negative charge, the strength of the beam of electrons is greatly reduced, because like charges repel. Thus the beam may be made either strong or weak. The direction of the beam is controlled by two pairs of plates. The plates of one pair are on either side of the beam, while the plates of the other pair are above and below it. If one plate of a pair is given a negative charge and the other a positive charge, the electron beam is attracted and bent toward the positive plate. By controlling the charges of these four plates, the beam of electrons can be directed up and down or sidewise as desired.

How does the television camera work? A television camera is a device which feeds current into a radio broadcasting set in proportion to the light and dark areas in the scene in front of the camera. It consists essentially of four parts. These are a regular camera lens, a glass vacuum tube containing a sensitive photoelectric surface, an electron gun, and a plate which collects the freed



One of the types of receivers used in television is this funnel-shaped tube. A beam of electrons passing between the two pairs of charged plates moves rapidly over the screen, making a chemical glow to produce an image.

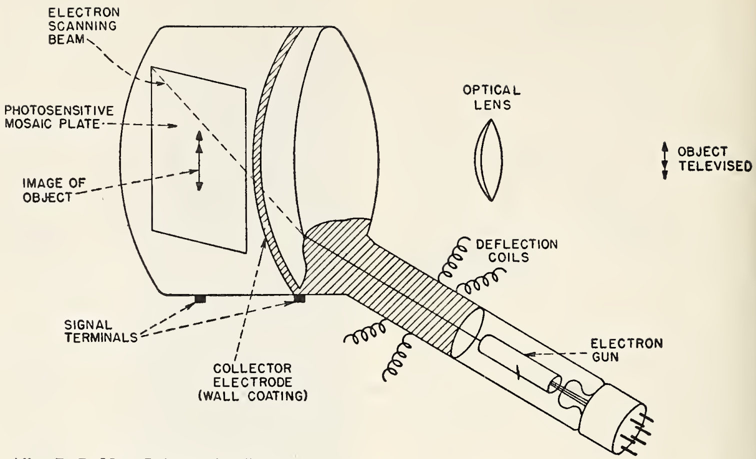
electrons. These may be arranged in somewhat different ways.

The camera lens projects and focuses the picture just as the lens of an ordinary camera does, except that the image is formed on the light-sensitive surface. This surface consists of a great number of tiny globes of silver, each coated with a thin layer of caesium. Each of these tiny globes is a miniature photoelectric cell. Where the light shines strongly on the surface, the globes have free electrons on their surfaces. Where less light shines fewer electrons are freed. These electrons, however, do not have enough energy to escape and go to the plate unaided.

Here is where the electron gun comes in. It shoots a beam of electrons back and forth across the light-sensitive surface 525 times for each picture that is formed. The electrons from the gun knock off the free electrons on the surface of the plate with enough force that they pass to the positively charged plate. The current from the plate is fed into a radio broadcasting system.

This sounds simple. There have been difficulties, however. In order for a motion picture or a television picture to show motion, at least 16 pictures per second must be presented on the screen. That means that at least 16 times per second the electron beam must sweep completely over the light-sensitive surface containing the picture, and a powerful enough current must be produced to broadcast. In order to get such a current the camera has been improving many times, and still bright light is necessary to get good television pictures.

How does the receiver work? The television receiver consists of a radio which picks up the broadcast program and directs the current into the picture tube. The picture tube includes an electron gun at one end, and a



Allen B. DuMont Laboratories, Inc.

This is the iconoscope, the sending tube of one kind of television camera.

flat or slightly curved wide screen opposite it. This screen consists of chemicals painted on the inside of the glass. When electrons from the electron gun strike this screen, the chemical glows, and a picture is made up of bright dots or lines. If you look at pictures in this book you will see that they are also made up of many dots.

The beam of electrons from the electron gun must sweep across the receiving tube exactly in step with the beam of electrons in the camera. The brightness of light on the receiving tube is controlled by the radio signal from the sending camera. When a bright light enters the camera, a strong current is produced and a strong radio signal is sent. This signal, received and sent to the grid of the electron gun in the receiving set, causes a strong beam of electrons to strike the receiving screen, and a bright spot is produced. When little light enters the camera weak waves are sent out, and the tube of the receiver becomes dark. Thus 16 or more times a second a complete picture of dots of light is built up on the end of the receiving tube.

In some receiving sets the picture on the end of the tube is either magnified or projected to a screen by lenses.

At the same time the picture is broadcast, the sound for the program is broadcast over an entirely separate system.

Television programs are now broadcast on very short waves which travel in straight lines like light. As a result very high towers are required for the antennae, and programs are not received dependably for much more than 60 miles from the station. A very expensive type of cable is re-

quired to carry television signals by wire. The programs are broadcast from the original station to a relay station, from which it is re-broadcast to another relay station, and so on, for national hookups. Television is much more complex and more expensive than radio.

What is radar? Radar is one of several devices which use a reflected radio wave to make a picture. Very short radio waves are reflected much as light is. When they are picked up by the right kind of receiving set they may be caused to make a picture on a screen, just about as a television set does. These radar type radio devices may be used to detect objects in the dark or in fog. A similar set of devices reflects radio waves to produce sound signals or to operate meters. The distance of a plane above the ground, the distance from the earth to the moon, and the distance in which a blind person can walk safely are detected by these devices.

Exercise

Copy the diagram of the television sending and receiving sets in your notebook. Add enlarged details from other diagrams.

A review of the chapter

Sound is a form of physical energy which travels in waves through the air or through other materials. It is produced by vibrating bodies. Pitch of sound depends upon the rate of vibration, the lowest sound we can hear being 16 vibrations per second and the highest about 20,000 per second. Pitch of strings is raised by tightening the string, shortening it, or reducing its cross section.

The telephone and telegraph depend upon use of a sender to change the strength of a current, a conductor to carry it, and a receiver containing an electromagnet to produce sounds.

The radio broadcasts magnetic waves set up by a current flowing through an aerial. The strength and frequency of the waves are controlled by a radio tube, which in turn is controlled by a microphone. The waves cut the aerial of the receiving set and are changed by tubes to current which controls an electromagnet in a loud-speaker.

Sound is recorded on a record by making grooves in it. The grooves cause a needle to vibrate when the record is played.

Wired pictures, and talking motion pictures depend upon use of the photoelectric cell, which produces a current in proportion to the strength of the light shining upon it. The recent development of television and radar devices provides two very useful means of electronic communication.

Word list for study

electronics	light valve	relay	resonance
phototube	kilocycle	teletype	pitch
electron gun	grid	modulation	code
rarefaction	facsimile	frequency	transmitter
percussion	radar	plate	amplifier
multiplex	decibel	sound track	wave length
amplitude			

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Sound is produced by vibrating bodies.

B. The energy producing sound causes waves in air and other objects.

C. Pitch depends upon the number of vibrations per second.

D. An electric current is a flow of electrons.

E. Moving electrons send out magnetic waves or radiations.

F. When a conductor cuts, or is cut by, a magnetic field, a voltage is generated which may cause a current to flow.

G. Like poles or charges repel each other.

H. Unlike poles or charges attract each other.

I. The strength of a current varies inversely with the resistance, or $A = \frac{V}{O}$.

J. Electrons are given off when the balance of energy in atoms is upset by heat or light.

List of related ideas

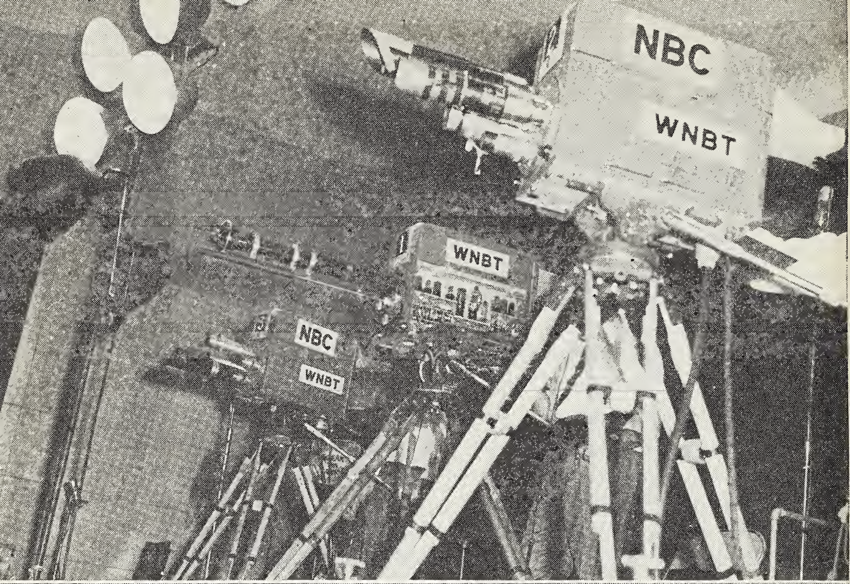
1. The voice is produced by the vocal cords.
2. A current flows in a photoelectric cell when light shines on it.
3. Sound waves can set objects into vibration to produce sound.
4. The phonograph pickup is a coil within a magnetic field.
5. A current flows when electrons move from the filament to the plate of a radio tube.
6. Echoes are prevented by use of porous materials in auditoriums.
7. No electrons flow from the filament to the grid of a radio tube.
8. The varying current in the telephone receiver operates an electromagnet.
9. A beam of electrons is bent toward a positively charged plate in an electron gun.
10. The telephone transmitter contains carbon grains which vary a current when they are moved.
11. Sounding one tuning fork may

cause another of the same pitch to vibrate.

12. The rate of vibration of strings is increased by tightening them.
13. When electrons collect around a hot filament they prevent other electrons from leaving the filament.
14. When electrons strike a metal target with sufficient voltage X rays are given off.
15. In wired photo a beam of light is reflected from a photograph to a phototube.
16. Current strength decreases rapidly as distance from the telegraph station increases.
17. The armature of the telegraph sounder moves when a current flows through the coils.
18. An alternating or varying current flowing through a primary coil produces a voltage in the secondary coil of telephones, radios, and other devices.
19. Sound produces vibration of the parts of the ear to stimulate the nerves of hearing.
20. Hearing aids sometimes conduct sound through the bones of the head.
21. The faster a siren disk is turned, the higher the tone produced.
22. Middle *C* is 256 vibrations per second, while high C is 512 vibrations per second.
23. Electrons, but not sound waves, travel over telephone wires to produce sound.
24. We regulate volume of radio by a rheostat which controls the current heating the filament.
25. Radio waves travel from an aerial carrying a current.
26. Radio waves striking an aerial cause a current to flow to the grid.
27. No current flows from filament to plate unless the filament is hot.
28. A phonograph record is cut by a magnetic recording device.
29. The needle of an ordinary phonograph is vibrated by the grooves of the record.
30. The central loop of a phototube is always positively charged.
31. A negatively charged grid in a radio tube stops the flow of electrons.
32. Putting a vibrating tuning fork on a glass makes the sound louder.
33. The vocal cords of a woman usually vibrate faster than do those of a man.
34. Singing near a piano sometimes produces a sound in the piano.
35. A current can be produced only when electrons are released from atoms.
36. Light shines through the film upon a phototube to produce sound in the theater.
37. An electromagnetic field moves from the aerial coil to the grid coil of the first radio receiving tube.
38. Fish can hear sounds of oars.
39. The longer a string the slower its rate of vibration.
40. Electrons from the filament move to the plate of a radio tube.

Some things to explain

1. Explain this statement: The development of improved communication and transportation, as the United States was being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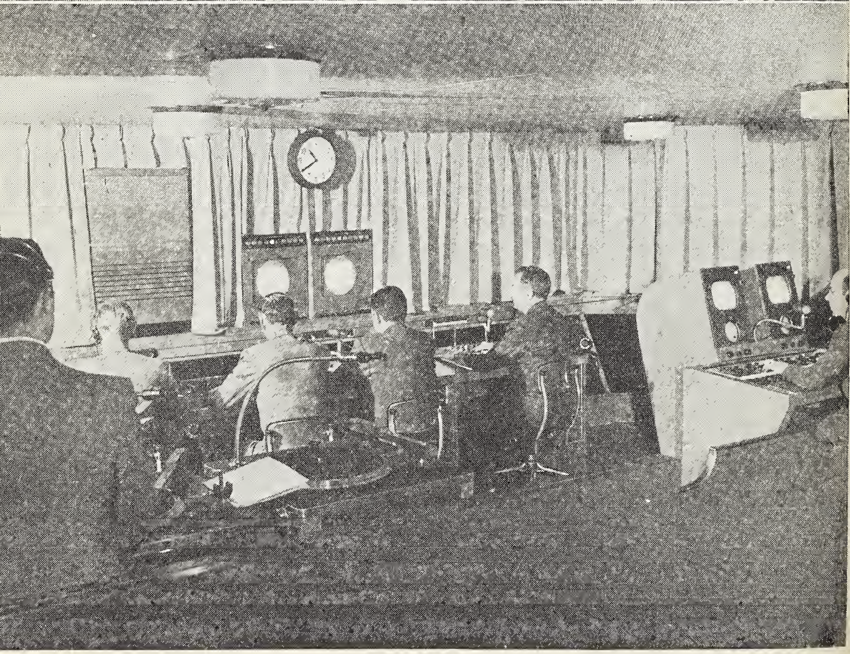


settled, is directly responsible for the various sections of the country remaining under the flag.

2. What do you think is the most important simple electrical device used in communication?
3. Do you think that the radio is being used for the good of all the people or only for the good of advertisers?
4. Does a molecule of air in a sound wave travel like a bullet or like a person in a swing?
5. What is the reason that snow crackles underfoot?
6. What is static? What new type of radio has no static?
7. How has television changed the popularity of radio in recent years?

Some good books to read

American Radio Relay League, *Radio Amateur's Handbook*

Bendick, J., *Electronics for Boys and Girls*

Benz, F. E., *Talking Around the Earth*

Compton's Pictured Encyclopedia

Dunlap, O. E., *Understanding Television*

Geralton, J., *Story of Sound*

Meister, M., *Magnetism and Electricity*

Morgan, A. P., *First Principles of Radio Communication*

Oslin, G. P., *Talking Wires*

Sill, A., *Communication Through the Ages*

Yates, R. F., *Boys Book of Communications*

Yates, R. F., *New Television*

←

National Broadcasting Company

The preparation of a television play involves many highly complex principles of science. Several cameras are used (*top*), each with special lenses for close-ups and distant shots. The pictures they take are flashed on different screens (*below*) from which the program director makes a selection to give the variety of scenes you see on your television set. The sound is also regulated by the engineers seated before each screen.

Allen D. Cruickshank, National Audubon Society

UNIT SIX

CONSERVING LIVING RESOURCES

Lois said, as she laid some materials on the table, "Although it may look as if I am going to demonstrate the preparation of a salad, that is not the purpose of my experiment. I am going to demonstrate the method by which liquids travel in plants."

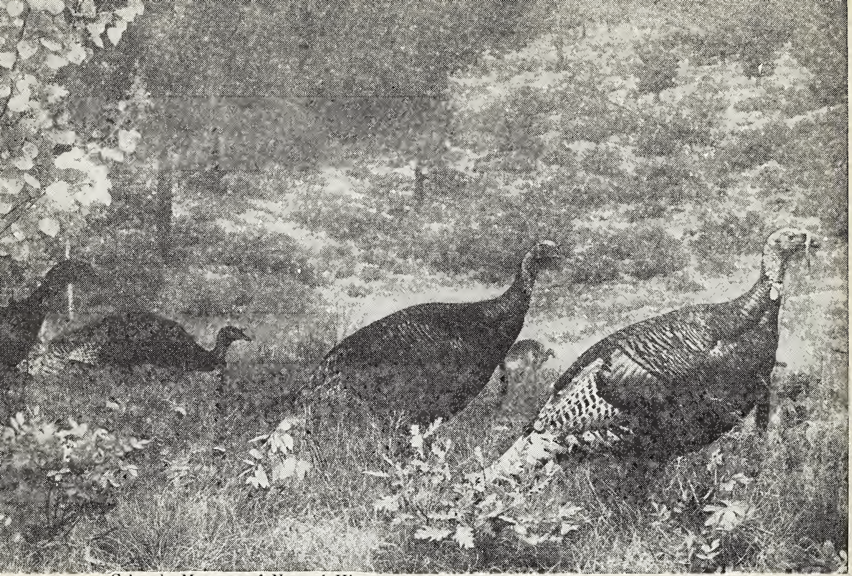
She quickly cut the top and bottom from a rutabaga, and with a fruit corer bored a hole in the top of the rutabaga. She made a smaller hole through the side of the rutabaga to the center hole, near the top, and thrust a piece of drinking straw into it. Next she stood the rutabaga upright in a dish of water.

She prepared a thick sirup by stirring sugar into hot water until some of the sugar remained on the bottom of the glass. Then she poured some of the syrup into the hole in the rutabaga, being careful not to pour in so much that it ran from the straw.

She explained as she worked, "We have learned that molecules are constantly in motion. The molecules of liquids, in particular, move rather freely. Some liquids are solutions—that is, they contain dissolved materials. Materials in solution seem to reduce the speed at which water molecules move. At any rate, when I put sirup into this rutabaga, and let the rutabaga stand in a dish of water, the water enters the rutabaga much faster than the sirup leaves it. The water creates pressure enough to cause the liquids of the rutabaga to rise. If we observe this demonstration from time to time during our planning period, we can see drops of sirup fall from the straw into the smaller dish."

"What is the name of this process or demonstration?" John asked.

Lois replied, "This process may be called either osmosis [ŏs·mō′sĭs] or diffusion."



Colorado Museum of Natural History

Wild turkeys were once fairly common in many parts of the United States. Now they are scarce because hunting and destruction of their natural homes have made conditions unsuitable to their survival.

Colorado Museum of Natural History

These white bears, which belong to a rare species found only in the Rocky Mountains, are eating berries which make an important part of their diet.

CHAPTER

11

Adaptations for Survival

There are so many kinds of living things—insects, weeds, flowers, birds, trees, bacteria, mushrooms, fish, and many others—that it may seem almost useless to try to study them. But to a scientist this great variety of living things does not seem so confusing. One of the first men who studied living things scientifically, Linneaus [lĭ·nē′ŭs], worked out a method of classifying plants by which those that are much alike can be studied together. Other scientists have discovered the principles which describe the functioning of all living things. Thus while living things differ greatly from one another, all have certain problems to solve, and many of them solve these problems in the same way.

We know that if a plant is green it can make food, while if it is colorless it cannot. Knowing this fact about plants enables us to know in a general way how it must live, and what it needs in order to live. If we can observe how a certain small animal is built, we can know whether or not it is an insect. If it is an insect, we know many things about it with no further study.

The chief problems of all living things are related to being able to survive in a world where food, air, water, space, and warmth are not available in unlimited amounts. All living things must produce young in order that their kind may survive. No matter what the plant or animal we may study, whether it be a whale or a horsefly, we will find many interesting ways in which that individual is fitted to survive in its surroundings.

Some activities to do

1. If you have a microscope available, obtain some living things to study which have been grown from hay or weeds. Put the hay or weeds in water in an open jar, leave the jar in a warm place for a few days, and then put a drop of the water on a

This brown bear, like all bears, hibernates in the winter. It is adapted to live in forest regions.

microscope slide and observe what living things it contains.

2. Put different kinds of roots and stems, such as willow twigs, potatoes, carrots, and geranium stems, into water colored with ink. Let them stand overnight, and cut into the stems or roots to see how far the liquid has risen.

3. Make a collection of plants, trying to get two examples of each of the three simple types of plants and 10 seed plants. Most plants can be pressed and kept dry. Label each plant according to the type to which it belongs. Some dried plants may be kept from shattering if dipped in paraffin. Plants may be kept in cellophane envelopes.

4. Introduce into the school aquarium some crustaceans which you find in ponds or streams. Study them.

5. Make a collection of insects, classifying them according to orders. You will need to study an insect book to do this. Mount them in a cigar box by pinning them through the thorax. Insects may be killed by dropping them into rubbing alcohol.

6. Set up as individual projects as many fresh-water aquaria as you can, using a variety of water plants and animals. In some, use fish; in others, insects; in others, crayfish; in still others, clams or leeches. Try to find a supply of plants which will live with the animals and provide them with oxygen. Algae provide considerable amounts of oxygen.

7. In a large, flat box put sand in one corner, sawdust in another, soil in another, and stones in another. Count out 100 radish seeds and scatter them over the box. Keep the box moistened, and at the end of a week and of two weeks count the number of surviving plants.

8. In a flowerpot filled with rich soil put bean seeds as thick as they will lie in a single layer, and cover them with a half-inch of soil. Keep them watered well, and observe what happens. Keep a record of the number of seeds used, and the number of plants surviving.

9. If a model of a dissected frog, fish, or rabbit is available, study its internal structure, and compare it with that of the honeybee.

10. When an animal such as a fish, chicken or a rabbit is being prepared for the table, observe the internal organs, identify as many as you can.

11. Collect frog eggs in the early spring. Bring them into the laboratory and place them in an aquarium. Watch them daily until they hatch. Try to keep the tadpoles until they develop into frogs. Consult reference books to learn what to feed them.

12. Paint two potatoes almost white on one side, blending the paint so that it gradually fades into brown, leaving one half wholly brown. Use another unpainted potato for comparison. Run stiff wires through all three potatoes. Put the light side of one painted potato underneath, and the light side of the other painted potato above. Place all three in a bare spot. Support them by sticking the wires in the soil, and observe them from a distance. Compare with the coloring of birds.

13. Find in a reference book microscope views of leaves, and make a soap sculptured model showing a leaf greatly magnified. Put in the various cells, a vein, and stomates.

Some subjects for reports

1. Report on one animal, explaining to what general group it belongs, in what environment it lives, how it obtains food, how it protects itself, what its chief enemies are, and how it survives changing seasons.

2. The work of Linneaus

3. The life and work of Charles Darwin

4. The life and work of Hugo de Vries

5. The lives and work of Schleiden and Schwann

6. The discoveries of Hugo von Mohl

7. Plants and animals which have recently become extinct

8. The most common birds, mammals, and insects in your locality

9. Special adaptions for protection and defense

10. Insects that mimic other insects

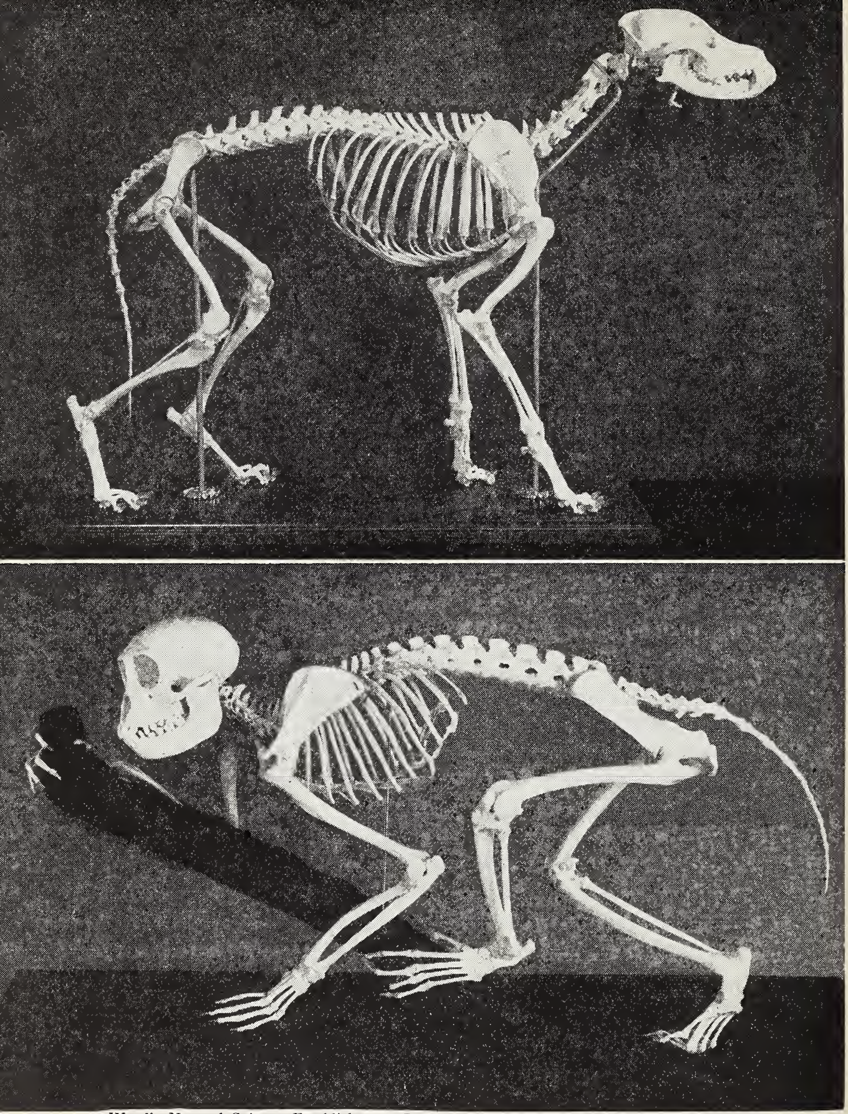
11. Poison and chemical defenses of animals

1. How are living things able to survive?

It would seem that in the great variety of soils, climates, and moisture conditions which are found on the earth, some places would be so poorly adapted for life that no living things could possibly survive. Yet in desert places we find the mesquite, a shrub, slowly working its roots as far as 50 feet through the parched soil for a tiny trickle of life-giving water. On the bare rocks of a mountain, where it would seem that no life could exist, we find dry, scalelike plants—lichens [lī′ kĕn]—growing.

In the frozen wastes, a red tint on the snow indicates the presence of algae—another simple plant. The ocean is filled with countless millions of floating organisms, some widely scattered and others tangled so close together that they retard the movement of ships. To live in all these different surroundings and to withstand the different conditions calls for different types of adaptations.

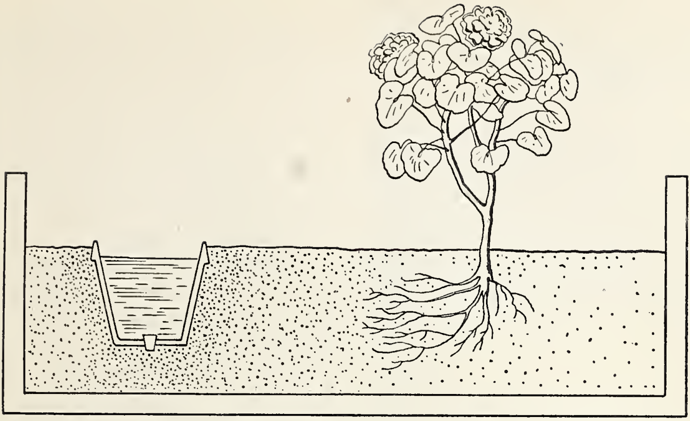
What are adaptations? Adaptations are the structures and types of behavior which enable



Ward's Natural Science Establishment, Inc.

Applying the principle that function depends on structure, compare the skeletons of the dog (*above*) with that of the monkey (*below*). Compare skulls, teeth, feet, leg and hip bones, and heel bones.

an organism to continue to live under certain conditions. Some living things perish because they are not adapted to a changing environment, while those that are adapted survive.



The seeking of water by growing roots is a tropism. The water is the stimulus, the increased rate of growth the response.

The environment includes all those things and forces in the midst of which an organism lives. Some of the factors in the environment are living things—other plants and animals—while other parts are nonliving. The living environment contains factors both helpful and harmful to an organism. All living things depend upon other living things, dead or alive, for food or for materials from which to make food.

Does structure determine how organisms live? Every living thing is adapted to a single, rather limited type of environment. The structure of the organism—the way it is built—determines what this environment is.

When we compare the structures of warm-blooded animals with those of frogs, snakes, earthworms, oysters, and other cold-blooded animals, these differences become still more apparent.

Plants are as different from each other as are animals. To make a comparison that is easy to see, consider the differences between a water lily and a cactus. The water lily has a thick, fleshy root from which comparatively few fibrous roots extend, for the struggle to find water and food is not a difficult one. The stems of water lilies are soft and weak. The leaves are broad and flat, and they float on the water instead of being held up by the stem. The cactus plant may have a system of fibrous roots which spread near the surface of the ground, where they may quickly absorb water from occasional rains. Other roots reach deep into the soil where they may obtain some water in drier seasons. The leaves of cacti are generally spines. The strong thick stems store water and make food.

How does behavior make animals fit their environments?

There are four general types of behavior. The simplest is called a tropism [trō′pĭz'm]. The turning of the sunflower to the sun is such a form of behavior. Tropism in the simple, one-celled animal, the amoeba, is shown when it is touched with a bristle, and its protoplasm flows away to the side opposite the point of stimulus. The seeking of water by plant roots and of light by the leaves are tropisms. The upward growth of stems is also a tropism.

Among higher animals there are three types of behavior: reflex behavior, instinctive behavior, and intelligent behavior. A reflex is usually rather simple in nature, and it is not learned nor is it controlled by thought. The inner workings of the bodies of animals are largely reflexes, for the muscles which control digestion, breathing, getting rid of wastes, and other life processes do their work without thought or direction. When you drop your cat wrong side up he quickly turns in the air to land on his feet. This is a rather complex type of reflex act.

The complex acts of most animals are instinctive. Let us see how the instincts of the grizzly, ground squirrel, and duck adapt them for winter. In the Rockies it is too cold for most animals to live active lives, and the snow is too deep for them to find food. In autumn the bear and the ground squirrel alike become possessed of great appetites, and eat until they are fat and sluggish. As winter approaches, they each go to a place to hibernate—the bear to a protected cave or hollow under rocks or to the roots of an upturned tree, the squirrel to his burrow. Then gradually they fall into deep sleep, and move as little as possible, until spring finds them restless, lean, and hungry.

The environment of the grizzly bear is the Rocky Mountains. The bear fits into this special environment in many ways. The bear is a mammal, which makes it necessary to live where it can breathe by means of lungs. It is a meat-eating animal, but it adds to its diet a limited amount of nuts and wild fruits. The grizzly is specially adapted for digging, for its powerful, curved claws may be three inches in length. The grizzly uses these claws to turn stones over and to tear up rotten logs in search of insects and grubs. The bear digs ground squirrels from their burrows. But the grizzly bear does not always limit his food to these small forms. He is so powerful that he can and does kill large animals, including deer and cattle, by seizing them and breaking their necks. The grizzly bear has a shaggy coat of white-tipped brown or black hairs which helps him to hide among rocks by blending into the background.

In the same environment in which the grizzly bear lives is found the ground squirrel. The ground squirrel also has claws well adapted for digging, and lives in burrows which it digs in loose, rocky soil. Its food consists

of seeds, fruits, field crops, and occasionally insects and small animals. Its fur is brown and mottled in color, making it blend into the color of the rocks and dry soil in which it lives.

It may appear at first that the ground squirrel and the grizzly have the same environments. In many respects they do. Yet their structures make these environments different in many respects. The grizzly does not need to hide from any enemy except man, while the ground squirrel can protect itself only by staying near enough to its burrow to dive into it when threatened by larger animals—hawks, coyotes, and bears. The grizzly need not consider these factors in the environment, for its great size and strength enable it to travel in safety where it wishes.

The flesh-tearing teeth of the bear and the gnawing teeth of the ground squirrel determine to a large degree the kinds of food each can eat. Their digestive systems differ in size and in the kinds of chemicals they secrete to digest food.

When greatly differing animals are compared, it is still easier to see how structure determines the environment in which the organism lives. A canvasback duck may live on a mountain pond in the region where the bear and ground squirrel live, yet its structure causes it to live an entirely different life. Its webbed feet make it unfit for life on land, but well fitted for swimimng. Its oiled feathers make it able to

L. W. Brownell

This ground squirrel is found in rocky regions of the West. It eats grasses and seeds and lives in a burrow.

float on the water. These ducks are so much at home in water that they dive to a depth of several feet to obtain the water plants and animals that live in the bottom of shallow ponds and lakes. The beaks of ducks are broad and scoop-shaped, and are provided with a comblike filter along the edges from which water runs from the food. The nest is located as near water as is possible and is hidden among reeds where the gray-brown feathers of the female help to conceal her.

The duck joins a flock of other ducks, and practices flying and landing to get into condition after a summer of living afloat on the water. Then on some cold morning the flock takes off and flies south to a warmer region.

You will note that behavior is dependent upon structure. The bear could not possibly fly south, nor could the duck hibernate. The steps that lead to hiberna-

W. J. Breckenridge

This ruffed grouse is "drumming" by beating his wings on a hollow log in order to attract a mate. Many kinds of male birds court mates.

tion must come in order, for unless the bear is fat he does not hibernate so early nor stay asleep so long.

Intelligent behavior is found in some of the so-called higher animals, but people are the only really intelligent animals. Some animals undoubtedly do some thinking and are capable of learning, but most stories about thinking animals are exaggerated.

Does environment determine adaptations? The kind of adaptations an organism has depends upon two things: its ancestors and its surroundings. No organism has more to develop from than it inherits from its ancestors but, even so, organisms of the same kind differ from each other. Factors in the environment are more favorable to one individual than the other. When deer are chased by wolves, the fastest runners escape, while the slowest are caught. In this way, the fastest become the ancestors of later generations. Over long periods of time—usually periods of thousands of years—most living things are selected to fit their environments by survival of those which

are better adapted for those environments. It is only intelligent animals that are capable of making rapid changes, and even in their case there are definite limits to the amount of change that can be made.

Exercise

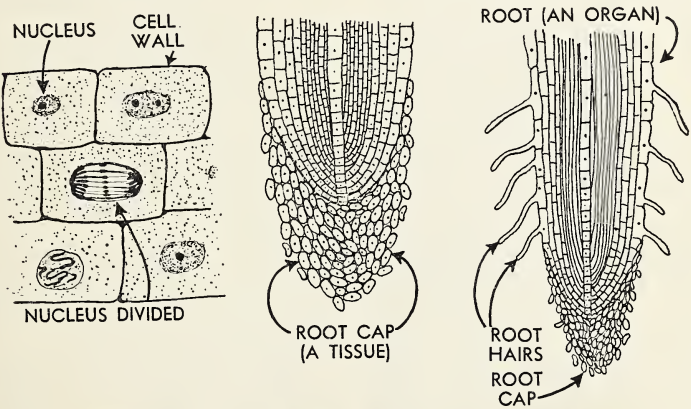
Complete these sentences:

—1— is a structure or change in an organism which fits it to live in its —2—. Claws, wings, and teeth are —3— which help the animal to adapt to its environment. The simplest type of behavior is —4—. Internal behavior of animals consists mostly of —5— acts. Migration and hibernation are examples of —6—, which are complex acts. Color of animals helps them to —7—. All living things depend upon others for —8—. The canvasback is a duck which obtains food by —9—. Two large groups of warm-blooded animals are —10— and —11—.

2. What is life?

Most of us do not have much experience with plants and animals, nor do we have means of studying living things too small to see with our unaided eyes. As a result we are likely to think of life only in connection with people, the large, four-footed animals, the fishes and birds, a few reptiles, and perhaps a few insects. We find that our experience with plants is confined almost entirely to a few common seed plants.

Yet no matter how limited our observations may be, we note immediately the difference between living and nonliving things. In living things certain processes go on that do not take place in nonliving things. These processes taken together make up the com-



All life processes take place in the cells. The cells are in various stages of division and growth (*left*). The root cap (*center*) is a tissue made up of cells. The entire root, including all its parts, is an organ.

plex chemical process called life.

Living things can release energy from foods. They can replace the materials used to produce energy. They can grow and produce others like themselves. They can move and can often direct their movement. Nonliving things cannot.

What is the stuff of life? If you could make thousands of observations of every imaginable living thing, you would understand better what life is. It is a series of changes that go on in a watery, jelly-like, fibrous chemical substance called protoplasm [prō′tō·plăz'm]. Protoplasm is the stuff of life, whether it is found in cabbages or kings.

The simplest living things are mere droplets of protoplasm which seem barely thick enough to cling together in the water in which they live.

While protoplasm does exist in very primitive forms, it usually is organized into cells, tissues, and organs, each adapted to perform specialized functions.

Of what parts are all complex organisms composed? A real understanding of life processes could hardly have developed without the microscope, for the basic building block of complex organisms is the microscopic cell. Cells were discovered nearly 300 years ago (in 1665) by Robert Hooke. But it was not until about 100 years ago that it was recognized that all living things are made of cells.

A cell usually consists of three or more parts. Around the outside there is usually a cell wall, which may be made of one of several materials. Some microscopic sea plants, or diatoms, make cell walls of lime and other rocklike materials. The cell walls of woody plants are made of cellulose, a material from which cellophane is made. Other cells may have walls of materials less familiar than these.

Inside the cell is the protoplasm, which is the living part and which constantly streams about. A central part of the cell is called the nucleus [nū′klė·ŭs]. It is thicker in appearance than the other protoplasm, and it seems to be the point from which growth and cell division begin. Cytoplasm [sī′tō·plăz'm] is the name applied to the other protoplasm.

In any animal containing more than one cell we are likely to find groups of cells similar to each other in appearance and function. These cell groups are called tissues. The lining of the mouth, the material of bark, and the groups of muscle fibers which permit animals to move are all tissues. Each tissue has some special function to perform in carrying on the life processes of the organism.

Groups of tissues which work together are called organs. Roots, leaves, eyes, claws, feathers, stings, and stomachs are organs.

What activities are necessary for life to exist? You already know that there are many functions necessary to make life possible. Among these are the ability

L. W. Brownell

Many animals change as they grow. This snake has grown a new skin beneath the old one and has shed the old skin.

to get food and air, the ability to move, and the ability to adapt to the environment. These life functions are closely tied up with certain properties or abilities of protoplasm.

The whole process of using food and releasing energy from it within the organism is metabolism [mĕ·tăb′o·lĭz'm]. Metabolism consists of two different types of activity. One of these is a building or constructive process; the other is a tearing down or destructive process. The constructive process is commonly carried on by plants when they make food, and it is carried on to some extent in the bodies of animals, as when cows produce milk. The constructive process also takes place in the cells where new protoplasm is built.

The destructive type of metabolism releases energy. This ability to release energy from food is common to all living things. Bacteria causing decay of an apple, a plant turning its leaves to follow the sun, and a tiger following its prey through the jungle are all using energy. The bacteria cannot make their own food, but instead absorb and use up the foods on which they grow. In the process they release heat, carbon dioxide, and water. They may also release other materials, depending upon the nature of the food they are using for their growth and activities.

The plant turning to follow the sun uses energy as truly as does an animal, and as a result also releases heat, carbon dioxide, and water from the food stored in its stem and leaves. The tiger requires a much more com-

L. W. Brownell

The lynx, or bobcat, is a common dweller of the northern forests. It eats a variety of small animals. It looks somewhat like a large housecat except for the hairs on its ears.

plex type of food than do the bacteria and plants, and as a result of using its food releases energy in more complex ways and produces more complex wastes. Yet from the body of the tiger heat is released and carbon dioxide and water are given off.

A second property of protoplasm is irritability—the ability to respond to a stimulus. The stimulus in the case of a plant may be sunlight, and the response a turning movement. The stimulus of the creeping tiger is hunger from within, and a complex combination of sights, sounds, and odors that seem to promise food. Every large muscle cell of the tiger's body responds to direction or stimulus of the nervous system to make possible the quiet, powerful movements necessary to follow a wild deer through dense thickets.

A third property of protoplasm is its ability to move. You know already that protoplasm constantly streams and flows within the cell, and that most living animals can move about to some extent. These movements, motion and locomotion, are essential for continued life.

A fourth property of protoplasm is growth. This process is closely related to metabolism, for until the building process provides sufficient material to increase the size of the organism, growth is impossible. You have already learned how many living things grow—how the chick hatches from the egg, how the fly maggot changes from a wormlike animal into a fly. Growth results from an increase in the amount of protoplasm within an organism, and from a reorganization of the protoplasm to form new

cells and tissues. Sometimes entire new organs are produced, as in the case when the fly develops wings in its pupa stage.

A fifth life process of protoplasm is the ability to reproduce. In the beginning stages of reproduction, living things are amazingly similar. For no matter how large or small an organism may eventually be, all start from the growth and division of a single cell. In the case of bacteria the cell divides into two bacteria, and reproduction is complete when the cells carry on their life processes separately. In the case of a higher plant or animal—a carrot or a sparrow—the division of the cell starts a most complex series of developments, which finally produces a large organism made up of perhaps billions of cells all working together.

Exercise

Complete these sentences:

Life is a series of —1— that take place in a substance called —2—. The simplest living things are composed of one —3—. In more complex organisms the cells work together to form —4— and —5—. —6— is the process of building up and destroying protoplasm. Wastes formed by the destructive process almost always include —7— and —8—. —9— is the ability of protoplasm to respond to a stimulus. Increase in size or change in organization of protoplasm is —10—. All life starts from one —11—. The central part of the cell is the —12—.

3. How are plants adapted for survival?

There are many kinds of plants each different in structure and adaptations from other kinds. Yet in spite of the differences between plants, they still are adapted in general to carry on their life processes in similar ways. All plants of each large group solve the problem of reproduction in a similar way: one group by cell division, another by development from spores, and another by growth from seeds. Because of these similarities, we can best study plants by learning to place them in groups where they naturally fit.

What are the simplest plants? There are two distinct types of simple plants. One type, the algae [ăl′jē], is capable of manufacturing its own food. The other type, the fungi [fŭn′jī], obtains its food from either living or dead materials.

Some algae are fitted to live in salt water, while other kinds are adapted to live in fresh water. Some grow on the trunks of trees.

These algae are made up of similar green cells which grow in chains.

Hugh Spencer

Hugh Spencer

This bread mold is threadlike, taking its food from the bread. The black circles are spore containers.

The pond scum seen growing in masses in ponds is composed of a great many algae plants. When examined under a microscope, this mass is found to consist of slender threads, each made of similar cells joined end to end. The algae occur in a variety of colors—green, red, and brown. The Red Sea gets its color from the algae living there. Brown and red algae which can live in hot water give color to the Mammoth Hot Springs in Yellowstone Park. Many algae are composed of but a single cell.

Fungi have no chlorophyll [klō′rȯ·fĭl]. If they use living matter as food, they are called parasites [păr′*ȧ*·sīts]. If they attach themselves to dead matter, they are called saprophytes [săp′rȯ·fīts]. Some of the fungi that take food from living plants are the cause of plant diseases. Rust on wheat and blights and mildews on other plants are examples. Bacteria and yeasts are very common fungi.

Mushrooms or toadstools are the only fungi recognized by most people. The common distinction between mushrooms and toadstools is that the former are safe to eat, while the latter are poisonous. But to a botanist the two words mean the same thing. Some of the nonpoisonous forms look very much like the poisonous varieties, and these cannot be told apart except by experts. Generally it is not safe to pick your own mushrooms for eating.

The part of the mushroom which we see above the ground is only the reproductive part. Below the ground are rootlike parts which absorb the food from things on which they grow. This is a useful adaptation for the environment. The parts underground are located where the food supply is. And since they cannot make their own food, they have no need for light. Location of the reproductive part above the ground makes it easier for the spores to be spread.

Mushrooms occur in a great variety of shapes. One of the most common is the umbrella shape. The top part is called the cap. On the underside of the cap are found gills in some plants and holes in others. If the cap of these

gill mushrooms is cut from the stem and placed gills down on a piece of paper, the spores will drop out to make a spore print. The lines of this spore print are arranged like the spokes of a wheel. The spores, however, differ in color. They may be black, white, pink, or brown.

Puffballs are another form of mushrooms. When ripe they are full of millions of tiny spores, which puff out as a powder when the puffball is squeezed.

This group, including both fungi and algae, which generally is called thallus [thăl′ŭs] plants, contains in all about 80,000 different kinds of simple plants.

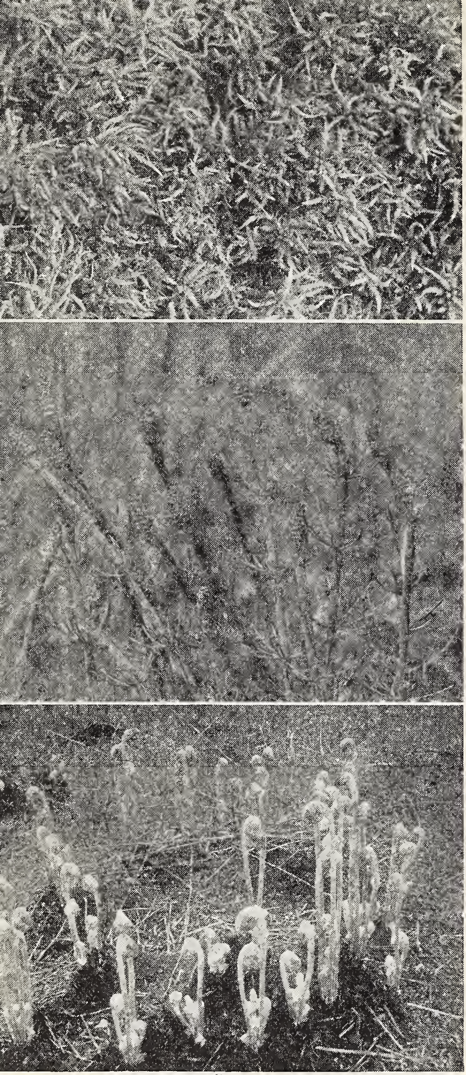
What are the mosses? The mosses are more complex in structure than thallus plants. They do not need to live either in or close to water. However, they are rarely found in extremely dry regions. Moss plants are small and never more than a few inches high. They may be found on the ground, on rocks, or on tree trunks. All are green and are therefore able to manufacture their own food.

They have stems and leaves but no flowers. Their system of reproduction is more complex than that of the thallus plants. The moss reproduces by developing through two stages. One stage produces a plant which develops the egg and sperm [spûrm, that part which is needed by the egg to help it grow]. From this plant there grows a second plant which produces the spores which are then scattered.

This poisonous fly mushroom is typical of the most commonly known group of fungi. The portion seen aboveground produces spores.

The mosses are generally unimportant to us. One kind, accumulating over long periods of time, forms peat bogs. Because the bog mosses absorb large quantities of water, they are much used as packing materials for living plants.

What are ferns? Did you ever see a "fiddlehead"? This name is often given to the opening buds of ferns. Instead of opening as do the buds of trees, they unroll up-



L. W. Brownell

This is the type of moss (*top*) that grows in swamps. These horsetails (*center*) show spore containers. These ferns (*bottom*) are in the "fiddlehead stage."

ward from the inside. On these buds you can find a fine plant down. Some birds use this down to line their nests.

In the spring new fern leaves grow outward from the old plant, leaving the central area without leaves.

The part of the fern plant that you most commonly see is the leaf. The leaves are generally divided into smaller parts, each part looking like a separate leaf. The stems are generally found underground, although in the tropics the main trunk may extend as much as 10 to 50 feet above the ground. At the top of this trunk is attached a mass of great leaves which may be as much as 20 feet long. Most ferns grow only in shaded positions, commonly being found in moist woodlands or shaded ravines. The horsetails are weedy, jointed, hollow-stemmed plants related to the ferns. They usually grow in thin, moist soil.

Fossils found in coal beds show that millions of years ago ferns grew to be the size of trees. Our coal beds were formed from the remains of these ancient fern forests.

What are seed plants? There are many more kinds of seed plants than of all other kinds of plants combined. Of the many kinds of seed plants there are some that are adapted to almost any environment. The seed is a structure which enables these plants to be widely scattered. Since the flower is the organ which produces seeds, all seed plants possess some sort of flower and develop some kind of fruit.

They have well-developed roots, stems, and leaves. The method of branching and form of leaf are important means of identifying the different members of the seed plants.

Seed plants bear their seeds in one of two ways. Most of the evergreens, such as the pines and spruce, bear their uncovered seeds on the scales of cones and are therefore called conifers [kō′-nĭ·fẽrz]. The second group of seed plants produce their seeds inside of some seed container. The seeds of some of these plants have a single seed leaf, while other seeds have two seed leaves, and still others have many seed leaves. Corn, wheat, lilies, and tulips produce seeds having only one seed leaf. The common trees, shrubs, vines, and most of the plants of the vegetable garden produce seeds have two seed leaves. The big trees, or giant sequoias [sė·kwoi′*ä*s], of California produce seeds having many seed leaves.

How may plants be classified? The plant groups just described are classified as they are because all members of a given group are similar in structure. The present system of plant classification was developed by Linnaeus during the eighteenth century.

Thus there are four large groups of plants: seed plants, ferns, mosses, and thallus plants. Within each of these groups the plants are further subdivided into smaller classes and these, in turn, into still smaller groups. Sometimes the classifications of the scientist are surprising to us, because we are likely to classify plants on the basis of their use rather than their structures. The scientist always uses structures as his basis for classification. Thus, to us the rose is a flowering plant and an apple plant is a fruit tree, but to a botanist they are both members of a closely related group.

DEMONSTRATION: WHAT ARE TWO KINDS OF SEEDS?

What to use: Seeds of corn, wheat, peas, beans, squash, radish, etc.; blotters or sawdust; dish.

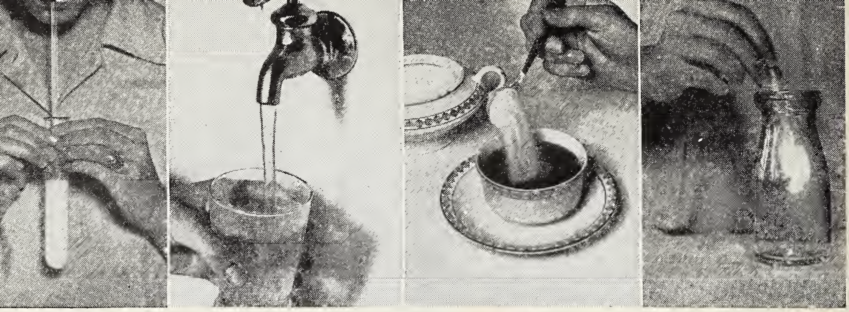
What to do: Soak the seeds overnight, then place them between moistened blotters or plant them in moist sawdust. Cover the dish to keep it moist. When the seeds have sprouted slightly, separate them to determine how many parts each seed has, and how the stems and roots grow from the seeds.

What was observed: Sketch the sprouting corn and bean seeds. Sort the seeds into two groups according to structure.

What was learned: What are two common types of seeds?

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: THALLUS PLANTS, FERNS, MOSSES, SEED PLANTS. *In the correct column write the following words:* algae, bacteria, corn, petunia, yeast, hollyhock, horsetails, peony, molds, mushroom, elm tree, rock moss, Boston fern.



These four pictures show the chemicals taking part in the chemical change: carbon dioxide plus water yield sugar plus oxygen. Explain the tests.

4. How do green plants make food?

Survival of all life depends upon a sufficient supply of food. Yet there is only one source of food—the green plant. No matter how well adapted an animal may be or how good the environment in other respects, if there is not a sufficient supply of green plants to provide food, life ceases to exist.

Are all plants green? As you know, there are two types of plants: those which are not able to make food and those which are. The plants which cannot make food are not green. There are a few red, brown, or blue-green plants which can make food. The foodmaking plants which are not green are chiefly algae.

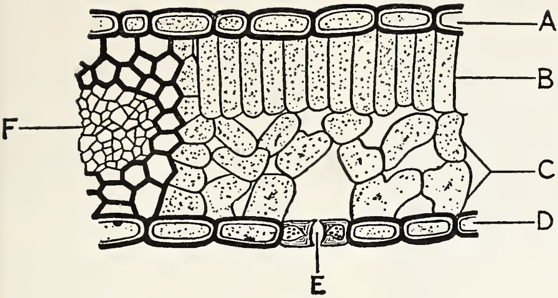
How do green plants make food? The process of making food is a chemical change—that is, energy taken in by the plant is used to change one kind of material to another. The process by which food is made is photosynthesis [fō′tō·sĭn′thė·sĭs], which means "light (*photo*) put together (*synthesis*)."

In order to make food, the plant must have a supply of materials. There must be chemicals in the plant to do the work, there must be a source of energy, and there must be some way to use the food and to get rid of wastes.

The food made as a result of photosynthesis is composed of the three elements carbon, oxygen, and hydrogen. The hydrogen is obtained from water, the carbon is derived from carbon dioxide, and the oxygen may be obtained from either water or carbon dioxide.

Water may be absorbed from the soil by tiny hairs on the roots of seed plants, or directly from water by water plants. There is always a small amount of carbon dioxide in the air, and most pond and ocean water contains dissolved carbon dioxide. Seed plants take carbon dioxide in through openings in the leaf called stomates.

The work of making sugar and starch is done by the chlorophyll which gives the green color to the plant. Chlorophyll is found



This cross section of a leaf shows the upper epidermis (**A**), the palisade cells (**B**), the spongy cells (**C**), the lower epidermis (**D**), the stomate (**E**), and the vein (**F**).

in the stems of some plants, as in the horsetails and cacti, and in the bark of many young plants. But most of the work of photosynthesis of larger plants is carried on in the leaves. One-celled plants contain their chlorophyll within the cell.

What is the source of energy? The source of the energy used in making food is the sun. It is light that the chlorophyll needs to do its work. The leaf works from sunrise to sunset. The length of the leaf's working day varies according to the latitude and the month. In the northern parts of the United States during the longest days of the summer the leaf makes food from 14 to 16 hours a day.

Leaves can make food in artificial light as well as in sunlight. Experiments have been done to learn the effect on the growth of plants of increasing the number of hours they were kept in the light. Some plants were kept in the light 15 hours daily, some 20, and some were kept in the light all the time. It was found that the plants matured more quickly when kept in the light longer. But there was a limit beyond which an increase in the hours of light did not further hasten the growth of plants.

What products do plants make? The products of photosynthesis are carbohydrates—starch and sugar. Probably the first product formed is sugar, which is then changed to starch. These two materials are readily changed one into the other. Carbohydrates are stored as starch, which is insoluble. The insoluble starch may be changed to a soluble sugar and, in this condition, carried in the sap to all parts of the plant. A square yard of leaf surface makes about three pounds of starch during the summer. In order to realize how much food plants make every year, one has only to think of the huge crops of corn, wheat, potatoes, apples, and foods of every kind that the farmers reap annually. All this food is but a tiny fraction of the food made by plants.

The chief work of chlorophyll is making sugar. But in the process another material, the element oxygen, is given off. All living

L. W. Brownell

The flowers of the pitcher plant grow from the cluster of pitcher-shaped leaves at the base. Explain how each leaf serves as a trap for insects.

things are constantly using up the oxygen in the air. Through the process of photosynthesis, the supply of this valuable element is renewed.

Plants make not only carbohydrates but also fats and proteins. Since protoplasm appears to be composed chiefly of proteins, the importance of proteins to plants as well as to animals is clear. Proteins contain the same three elements as do carbohydrates—carbon, hydrogen, and oxygen—but in addition they also contain nitrogen and some other elements, such as sulfur and phosphorus. The first three elements are obtained from starch; the other elements are obtained by the plants from minerals in the soil or in water.

The exact process of protein-making is not well understood; but some facts regarding it are known. Proteins are made from starch and mineral salts. Neither chlorophyll nor light is necessary for making protein.

How do plants get rid of water? While the seed plant is making food and giving off oxygen, it is also giving off excess water through the stomates of the leaf. This process is called transpiration [trăn′spĭ·rā′shŭn]. The amount of water thus given off is very large. An experiment carried on in Kansas showed that a corn plant lost nearly two barrels of water in a single season. This was nearly 100 times as much as the plant needed for all purposes except to replace that lost by transpiration. This large amount of water is needed to provide the small amount of mineral salts required by the plant.

As the water reaches the outer surface of the leaf, it evaporates and passes into the air as water vapor. The amount of water lost by transpiration varies greatly from day to day, depending on such factors as the temperature and humidity of the air. Within certain limits the amount of water transpired is controlled by the guard cells of the stomate. Generally they are open during the day and closed at night. The stomates also tend to close during the day when the supply of water in the leaves is deficient.

DEMONSTRATION: IS THERE STARCH IN GREEN LEAVES?

What to use: Green plant, alcohol, burner, beaker, iodine, pin, black paper.

What to do: On a large green leaf pin a smaller disk of black paper, and leave it for 24 hours. Set the plant in sunlight. Remove the leaf, take off the paper, and boil the leaf in water a few minutes. Dissolve out the chlorophyll in alcohol. With iodine, test the leaf for starch.

What was observed: Did the leaf turn dark blue all over? What does this color indicate?

What was learned: Is starch manufactured in the part of the leaf not exposed to sunlight?

Exercise

Complete these sentences:

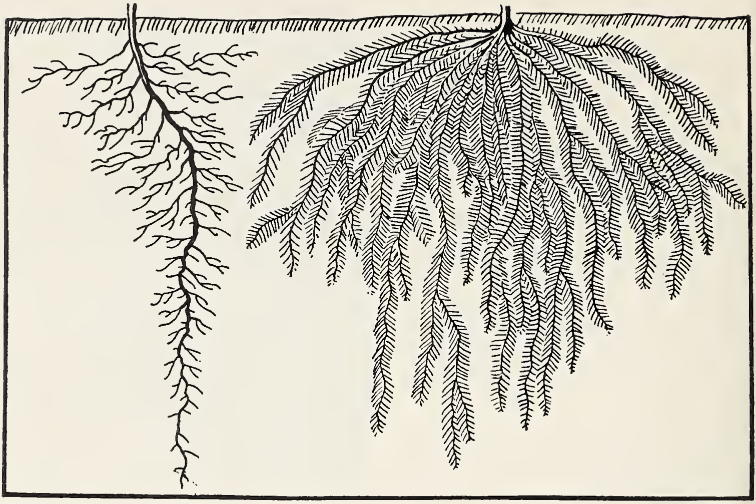
Starch is manufactured by green plants from water and —1—. Giving off water by the leaves of plants is called —2—. —3— is the process of making food. In the process of photosynthesis the gas —4— is given off. Proteins are made from starch and —5—. If a growing leaf is placed under a tumbler, —6— will collect on the inside of the tumbler. The energy needed by plants for manufacturing starch comes from the —7—. The green substance in the leaves is —8—. The process of —9— is the basis for the world's food supply. The small openings in the skin of the leaf are called —10—.

5. *What adaptations help plants to make food?*

In order to carry on the important function of making food, all plants have special adaptations. Of course the most important of these is the presence of chlorophyll. But other adaptations are also necessary in order to provide light, mineral food, water, and carbon dioxide to the part of the plant which makes the food. Some sea plants are light enough to float on the surface where they can get light. Other plants root in the lake or ocean bottom and send up long stems to the surface to reach light. While each kind of plant has its own adaptations, it is the seed plants which have the most successful adaptations for getting the things needed for making food.

How do roots help seed plants to make food? The root systems of most seed plants are quite extensive. If a small plant is carefully dug up so as to keep all the roots, it will often be found that this system is even larger than the part above ground. Alfalfa plants sometimes send their roots 20 feet deep in the soil. To include all the roots of a single grass plant, it is necessary to wash away more than a cubic yard of soil.

There are two types of roots, the taproot and fibrous roots. A



The taproot and the fibrous roots are the two systems common to seed plants.

taproot consists of a single large branch that grows straight down, giving off smaller branches. A fibrous root is composed of many small branches of about the same size. The beet plant has a taproot, and the grass plant a fibrous root.

A root has three main regions. Covering the end of the root, like a thimble on a finger, is a root cap, which protects the tender parts beneath. Just back of this cap is the growing region of the root. The root does not grow in length in any other of its parts.

The most important part of the root in absorbing water and minerals is the root hairs. They are found only near the growing tips of the young roots. As the roots grow longer, new root hairs appear just behind the tip, the older hairs meanwhile disappearing. They are very numerous, for there are sometimes as many as several thousand to an inch. Each hair is a tiny, tubelike cell with a wall so thin that soil water can pass through it. The root hairs cling closely to the particles of soil and increase greatly the surface used for absorbing water.

The process by which the water passes through the walls of the root hairs is osmosis. The walls of the root hairs act as membranes. The water in the soil is less dense than the cell sap, which contains sugar and other dissolved materials. Under these conditions the water passes from the less dense to the denser liquid. That is, water from the soil passes through the wall of the root hair into the cell sap. The pressure of osmosis forces water upward through the root which serves to carry water to the stem of the plant.

In order that a plant may stay where it can obtain a supply of water, it must be anchored in the soil with its root hairs in close contact with soil particles. Roots serve as anchors and foundations of the plant by developing a rigid structure and by wrapping themselves closely around soil particles. Corn plants have special roots which serve as braces to support the stem. Almost every plant has some adaptation whereby its roots serve to support the stem.

How does the stem help to make food? The stem has two important functions in foodmaking. It must serve as a transportation system, and it must either support the leaves or itself carry on the foodmaking process. There are two types of stems common to seed plants.

Trees and many other plants have stems with the parts arranged in rings. The outer layer is the bark, the inner layer the pith. Outside of the pith is the woody part, and the part between the bark and the wood is the cambium [kăm′bĭ·*ŭ*m]. The cambium is made up of a layer of cells from which growth proceeds. The woody part of stems more than a year old is really dead, but serves the important function of strengthening the plant. The newly formed wood carries the water and dissolved minerals from the roots to the leaves, while the newly formed bark carries food from the leaves to the roots. Pith is a storage place for food.

Another type of stem is represented by the corn plant and other grasses. The bundles of tubes which carry water and food are scattered throughout the pith inside the stem, and in each bundle some tubes carry water up the stem and other tubes carry food down the stem. As seen under the microscope, the larger tubes are the ones which carry water.

The stem of the bean plant twines around a support to lift the leaves toward the light. Find a grape, a garden pea, and an English ivy to compare with the bean as to their manner of climbing.

For holding the leaves to the light there are many interesting adaptations. The trees grow so tall that they rise above other plants. Some low plants branch

in all directions in order to expose the leaves to light as much as possible. Certain plants develop as vines which climb and twine around any support which can be used to hold leaves to light. The grapevine has special stems called tendrils which twist around the support. The leaf stalk of the nasturtium twists around a support to hold up the plant. The woodbine stem produces aerial roots which attach themselves by means of dislike suckers to the support on which the vine is climbing.

The stem of the cactus plant actually makes the food. The leaves are developed as spines and do not contain chlorophyll.

A few plants have stems which grow underground and send up branches at intervals in search of a suitable place for growth. One of the most common of these is quack grass, a plant which is very successful in competing with other plants for food and light. The potato is an underground stem used for storage of food and for providing a place for buds to develop for growth a year after the potato was formed.

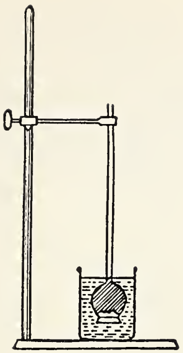
How do leaves help in making food? The leaf is generally the food factory of the plant. In order to reach the light, leaves are provided with petioles [pĕt′ĭ·ōl, leaf stalks] which twist in such a way that the flat part of the leaf—the blade—is turned toward the light. The leaf has a complete system for circulating water and food. This system consists of the veins, which are made up of the same kinds of bundles of tubes as are found in stems. The veins of grasses and related plants are parallel, while the veins of many other plants are arranged to form a network.

What tropisms help the plant to make food? Most of the tropisms of plants are concerned with making food. The turning of the leaf on its stalk to reach light is such a type of behavior. You recall that roots grow toward water. This tropism is of utmost importance for the survival of the plant. The tendency of roots, under the influence of gravity, to grow downward and of stems to grow upward is also essential for the success of the plant in making food. The opening and closing of the stomate by the guard cells is another tropism essential to conserving moisture when the plant is becoming dry. Also under conditions of dryness leaves of many plants roll and thus expose less surface to the sun and air.

DEMONSTRATION: WHAT IS OSMOSIS?

What to use: Thistle tube, pig bladder, sugàr, rubber band, beaker, ring stand, stopper.

What to do: Put the stem of the thistle tube in the stopper. Fill the funnel end of the thistle tube with thick sirup, holding a finger over the small end to keep the tube full of air. Put the pig bladder or a sausage casing over the large end of the tube. The sirup should rise in the stem about an inch. Put the large end of the thistle tube in a beaker of water, with the



level of the water and of the sirup the same. Support the tube on the ring stand, as shown in the diagram, by holding the stopper with a clamp.

What was observed: Can you see that the water has risen in the tube at the end of an hour? At the end of 24 hours?

What was learned: What happens in the process of osmosis?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: root hairs, osmosis, wood, bark, bundles of tubes, cambium, minerals, water, sirup, stomate, light, food, tropism.

6. What are some simple animals?

Most people generally know little about the simplest animals, because they are small and because they are not directly important to us. Yet there are at least 10 large groups, or phyla, of animals so simple that they have not developed an internal skeleton for support of their bodies. These animals range in size from one cell to several hundred pounds in weight, and vary just as much in structure as in size.

What are some one celled animals? We cannot hope to become familiar with all the 15,000 kinds of one-celled animals. These microscopic animals may live in the sea or in fresh water, in the bodies of other animals, or on moist soil. You can obtain some specimens for study by putting a handful of hay in water or by growing water weeds in a battery jar. In the scum that forms on the surface of the water one-celled animals usually can be found.

A common animal grown in this way is the amoeba [*ȧ*·mē′b*ȧ*]. It is about $\frac{1}{100}$ of an inch long, and is a nearly colorless, jelly-like mass of irregular shape. The nucleus is visible under the microscope. The cell constantly changes shape as its protoplasm forms bulges on one side or the other. Motion by this means is slow. To obtain food, the amoeba wraps its body cell around material it comes in contact with, digests what it can by chemicals produced in the cell, and then moves away, leaving the undigested material behind.

Another animal found in the scum from the jar of water is the paramecium [păr′*ȧ*·mē′shĭ*ŭ*m]. It is also a one-celled animal, but it has a definite shape—somewhat like a slipper with a pointed toe. Along one side is a groove

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Although the amoeba is called the simplest animal, its one cell carries on many complex life functions. Can you see its nucleus?

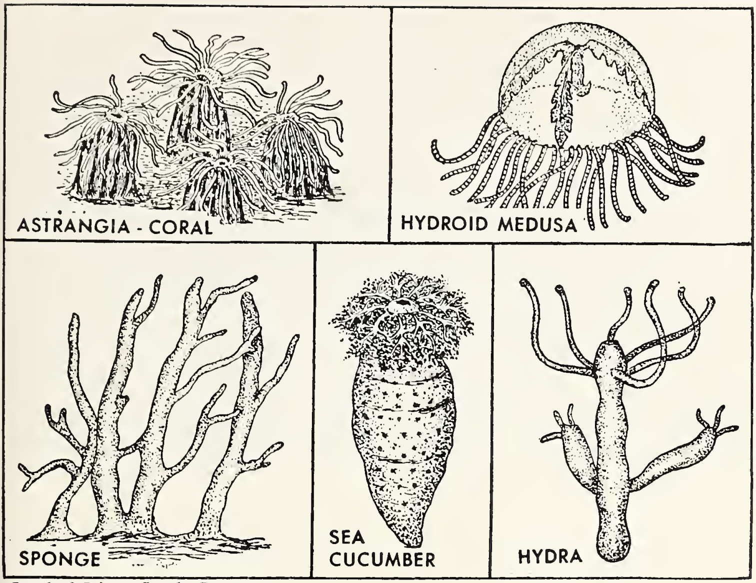
which leads to a mouth. Inside the cell a tiny droplet forms in which wastes accumulate, and this drop is thrown off through the cell wall. The cell is covered with hairlike growths called cilia [sĭl′ĭ·ȧ], which are used to produce movement. The paramecium rotates as it moves either forward or backward, by whipping its cilia in the water.

Are sponges animals? Sponges always live in water, and usually in salt water. They lie anchored on the bottom of the sea or lake, and depend upon currents of water to bring them food. The cells grow in vase-shaped groups. Water is circulated into the open end by means of cilia, then into the central cavity, and out through the open end. The cells lining the pores digest food and pass the digested food along to other cells. These vase-shaped groups of cells may form huge clusters, or may be almost microscopic in size. The common bath sponge is made up of skeletons of many animals. The skeletons of sponges are not internal skeletons, but rather are made up of horny fibers or glassy or limy materials.

What animals have hollow bodies? There are several groups of animals—the corals, the hydras, the sea anemones, and the jellyfishes—which have hollow bodies. All live in the water, and most of them live in salt water.

The hydra is found in fresh water, and is not more than a quarter of an inch long, and about as thick as a pin. It is made up of a hollow tube, and attaches one end to a stick or other support. The free end has a ring of six finger-like arms, arranged around an opening called the mouth. These arms, called tentacles, are used in obtaining food. On these arms are many small stinging cells.

The hydra moves in various ways. It waves its tentacles and expands and contracts its body. It can also move along by sliding the lower end of its body along its support, or it can move like a measuring worm. It sometimes walks by using its arms as legs, or



Standard Science Supply Company

These animals live in water. The individuals are small, but they sometimes form large colonies. The hydroid medusa is a stage of growth of some hydra, in which the animal swims like a jellyfish.

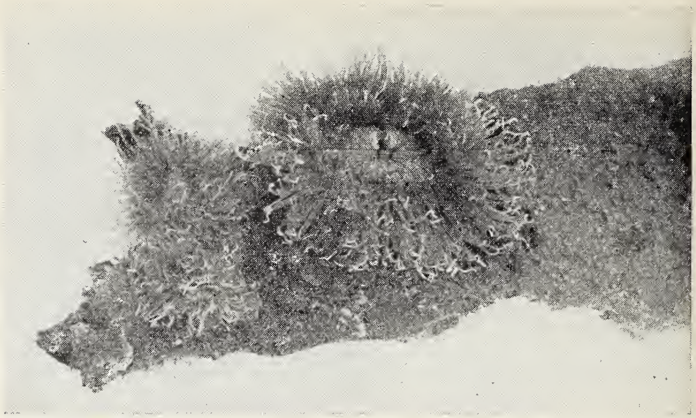
moves by turning slow somersaults.

The corals live in warm, shallow water in huge colonies. They build a kind of skeleton of lime. Each generation grows on top of the preceding generation, leaving behind materials which become part of the rock. The Great Barrier Reef of Australia, which was formed by corals, is more than a thousand miles long. Other types of corals form circular islands called atolls. Others grow near shore to form shore reefs. The corals are thus important rock-formers.

The sea anemone can commonly be found on rocks along the seashore at low tide. It looks as much like a flower as an animal.

Jellyfish usually are free-floating animals, and are about 97 per cent water.

How is the starfish adapted to live? There is an interesting group of animals with their parts arranged like the spokes of a wheel. This group includes the starfishes, the sea urchins, the sand dollars, sea lilies, and sea cucumbers. The most common of these is the starfish, which lies mouth down on the sand along the seacoast. The mouth is in the central part and is surrounded by five arms. The animals of this



L. W. Brownell

The sea anemone looks more like a flower than an animal. Its body is hollow, and it takes food into its central cavity.

group have spiny skins, and generally are quite firm in structure.

How do the worms live? There are several groups of worms, each different from the others. The flat worms are simple in structure and many are parasites in the bodies of other animals. Some live in snails, some in fish, some in higher animals. The tapeworm of man is such a worm, as is the liver fluke of sheep.

Numerous roundworms are also parasites, and are simple, tubelike animals. The hookworm and the trichina worm, which cause human illness, are members of this group.

The most complex worms are segmented, that is, their bodies are divided into ridges separated by grooves running around the body. The earthworm lives in moist soil through which it burrows to obtain food. In making a burrow, the worm passes soil into its mouth, through the crop, gizzard, and intestine, and out of the body. The worm backs up to the surface to get rid of the soil, which is left at the opening of the burrow in little piles of dirt called castings. In this way the worm is able to burrow deep into the soil, usually to a depth of three or four feet. The earthworm comes to the surface at night to feed on dead leaves and grass.

Because the worm breathes through its skin, it must be kept moist. This explains the fact that we see earthworms above ground only after rain.

Earthworms have simple nervous systems, quite complex digestive systems, special organs for getting rid of wastes, and means of circulating body fluids. They reproduce by laying eggs.

Most segmented worms are not parasites. A common parasite in

L. W. Brownell

These long, or soft-shelled, clams belong to the group of mollusks which are the soft-bodied animals. Why does a soft-bodied animal need a shell?

this group, however, is the leech.

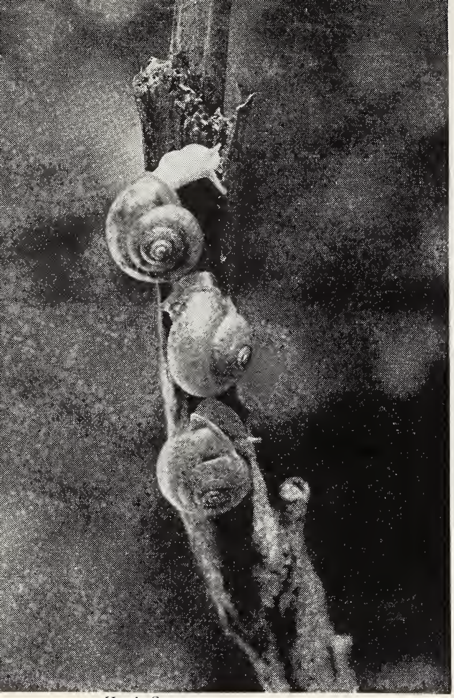
What animals have soft bodies? There are more than 60,000 different kinds of mollusks, which are the soft-bodied animals. This group includes snails, clams, oysters, squids, shipworms, scallops, and octopuses. Most members of this group have a shell which grows from a thin membrane, called the mantle, lining the shell. The shell is made of calcium carbonate, or "lime." Most members of this group have a muscular *foot* which contracts and expands to do the work of moving, digging, and holding to surfaces.

The snails have a single shell which is coiled spirally. Most snails live in water, but a few live on land. The common snail has a head, bearing a mouth and feelers, and a foot used for crawling. The slugs are similar to snails, but have no shells and live on land.

The oysters, clams, and scallops have shells divided into two parts, called valves. These are hinged on one side so that they may open or close. Most of this group live in salt water, though some live in lakes and rivers. All have means of circulating water through their shells and bodies to provide a supply of food and air, and to remove wastes. If you have a clam in your aquarium you can see the current of water it sets up.

Shipworms are mollusks which bore into the wood of piers and ships just below the water line. They are quite destructive of docks and piling.

The shellfish are quite complex, for they have well-developed digestive and excretory [waste eliminating] systems.



Hugh Spencer

These three garden snails live on land. They leave a trail of slime.

Their nervous systems are simple. They reproduce by means of eggs.

The large mollusks are the octopuses, the cuttlefish, and the squids. Some members of this class have no shell at all. The cuttlefish has an internal shell called cuttlebone. It is used as food for canaries. Some members of this family can move in a peculiar way. They fill an opening called the mantle cavity with water, and suddenly force it through a small tube. They move rapidly through the water on the principle of a rocket.

The squid can protect itself by ejecting into the water an inky fluid which conceals it from its enemies. The octopus and squid have a row of arms adapted for seizing their prey. The mouth is in the central part of the body.

Exercise

Make a table by ruling your paper into five columns. Head the columns as follows: ONE-CELLED ANIMALS, HOLLOW-BODIED ANIMALS, SPINY-SKINNED ANIMALS, WORMS, MOLLUSKS. *Classify every animal mentioned in this problem in the correct column.*

7. What animals have jointed feet?

As long as animals are limited in activities by simple structures, they do not adapt themselves well to complex environments. You probably have noted that most of the simple animals live in the sea or in some other place where the problems of getting food and surviving do not require any complex behavior. It was not until the development of a satisfactory skeleton and the resulting improvement in means of movement that any group of animals became outstandingly better adapted for survival than others.

There are more than three times as many kinds of arthropods [är′thrȯ·pŏd, an animal with jointed feet] as of all other kinds of animals combined. The successful adaptation of the arthropods results from several features of their structure. They have skeletons made of a strong, light

(Center right) © General Biological Supply House. (All other photos) L. W. Brownell

These animals represent five groups of the arthropods. How do we recognize the centipede, the crab, the spider, the lobster, and the scorpion?

material called chitin [kī′tĭn]. The skeleton is located on the outside of the body in such a way that it serves to protect the complex inner structures of the animal. It also serves as a framework on which wings and legs are attached. Muscles are attached to

the inside of the skeleton. Some of the arthropods can move about more effectively than can members of any other group of animals. All arthropods have quite well-developed nervous systems which control their complex organs. This nervous system operates by instinct.

The arthropods include several large groups of animals—insects, spiders, crayfish, crabs, lobsters, centipedes, shrimps, sow bugs, and barnacles. The three biggest groups of arthropods are the insects, the hard-shelled animals, or Crustacea, and the spiders.

What are the hard-shelled animals? The hard-shelled animals—the lobsters, crayfish, and crabs—generally live in water. They vary greatly in size, for the smallest are almost microscopic, while the largest lobsters may attain a weight of 14 pounds. They breathe by means of gills.

The crayfish is a typical crustacean [krŭs·tā′shăn]. It is found in rivers and lakes, where it hides under rocks and logs by day. From its hiding place it comes out at night to feed. It eats small water animals.

The crayfish grows inside its skeleton, but the skeleton does not increase in size. When the crayfish is too big for its skeleton, the old skeleton splits down the back, and the animal crawls out, leaving the old shell. It then grows a new skeleton. This process of shedding the shell is called molting.

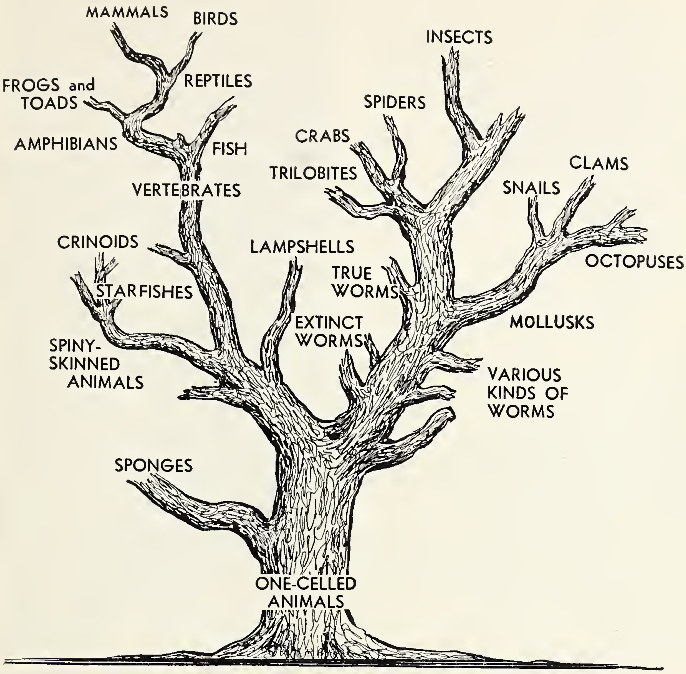
There are many appendages [ă·pĕn′dĭj, an external organ] upon the body of the crayfish. The large pincers serve for defense and attack. Some of the others serve as sense organs, some serve as means of securing and chewing food, and some of the smaller appendages on the thorax, or midsection, serve as legs. These appendages have the power of growing on again if broken off. Growth starts at a certain joint and continues until the new appendage is as large as the old.

What are the spiders and their relatives? The spiders and their relatives are numerous. They live on land, and have either leaflike external lungs or breathing tubes, or both. All members of this group have eight legs, and do not have antennae, or feelers. Some of them—the scorpions—have pincers. All of this group eat by sucking the juices from their prey.

Scorpions are noted for their poisonous sting, which is located at the end of the jointed abdomen, or "tail." They live in the warmer sections of the United States. Their food consists of large spiders and insects, which they seize with their pincers and sting to death. Scorpions do their hunting at night.

Unlike scorpions the spiders have no pincers and no poison sting on their abdomens. The head and thorax are grown together, and the abdomen is not divided into segments or joints. Most spiders have four pairs of eyes.

The webs of spiders serve not



This "tree" shows the relationship existing between different groups of animals. It is believed that the animals on the higher branches developed through stages similar to the simpler forms below them on the same branches.

only as traps to catch food, but as elevators and bridges. Many spiders travel by spinning threads which are carried by air currents, taking the spider along. Some spiders spin bags in which they carry their eggs. Others spin bags, but after filling them with eggs leave them in a safe place for the young to hatch. Some spiders carry their young on their backs.

The only deadly poisonous spider in the United States is the black widow female, which is glossy black, with a red or orange hourglass marking on the underside. The tarantula bite is somewhat poisonous but not generally deadly. Most true spiders can bite, injecting enough poison to cause painful swellings.

The ticks and mites are dangerous parasites that suck blood from poultry, game animals, farm animals, and human beings. In addition to being unpleasant and tending to weaken the animal on which they live by withdrawing blood from it, these parasites carry a number of dangerous diseases.

How are insects adapted for

survival? In some ways the insects are the world's outstanding specialists. Most of them are better adapted for flying than are any other animals except birds. Some insects have the most highly developed social groups except those of man. Some insects are clever builders. Others are fierce fighters.

The insect differs from the spider and crustacean in several important ways. Its body is divided sharply into three parts: the head, the thorax, and the abdomen. A few insects have no wings. One large group, which includes flies and mosquitoes, has one pair of wings. Most insects have two pairs of wings. All insects have six legs, and have feelers, or antennae, on the head of adult forms.

The small size of insects is a distinct advantage for survival for they can hide easily, and require a relatively small supply of food. The tough skeleton and light weight of an insect makes flying at high speeds practical, for it does not dash itself apart upon landing.

Insects are able to produce large numbers of offspring, which is also an advantage. The average female insect probably lays about a hundred eggs, although some may lay many more than this. Insects may grow rapidly. A female housefly lays 150 eggs which develop into adult flies in two weeks. It is estimated that if all the descendants of a female plant louse lived, at the end of a single summer they would be numerous enough to form a chain around the world. Some insects in their development may go through four stages —egg, larva, pupa, and adult— while others grow through three stages—egg, nymph, and adult. Insects in the larva stage are specialized for eating large amounts of food in order to grow rapidly. Many insects provide special care for their young.

Although the behavior of insects is not intelligent but instinctive, they are able to carry on activities of the most complex sort. The female mud-dauber wasp will catch and sting spiders until they are paralyzed, and put them into the nest with her eggs to provide her young with food. The helpless spiders cannot harm the young wasps, but because they are alive they do not decay or spoil. The young wasps are assured a supply of fresh food, although the mother never sees them. For when the female mud dauber has completed her task, she caps the egg cells over and leaves, never to return.

What are some other arthropods? The millipedes are commonly called thousand-legged worms, and the centipedes hundred-legged worms. Both are made up of many segments. The centipedes have one pair of jointed legs on each segment, while the millipedes have two pairs of legs on each segment. Only the centipedes have poison jaws. The millipedes eat vegetable matter, but the centipedes eat insects.

(Center right) © General Biological Supply House. (All others) U. S. Bureau of Entomology and Plant Quarantine.

The adult insects are a female black digger wasp (*top right*) and a swallowtail butterfly (*center right*). The larvae are a tent caterpillar (*top left*) and a hickory horned devil (*bottom*).

Exercise

Complete these sentences:

The animals which have jointed feet are called —1—. They have a —2— outside the body. The crayfish and crabs live in —3— and

breathe by means of —4—. The spiders breathe by means of —5—. The bodies of —6— are divided into three parts. —7— have eight legs while —8— have six. The only arthropods with wings are —9—. The —10— stage of insects is especially adapted for food-getting. The —11— include the lobsters, crabs, and crayfish.

8. What animals have backbones?

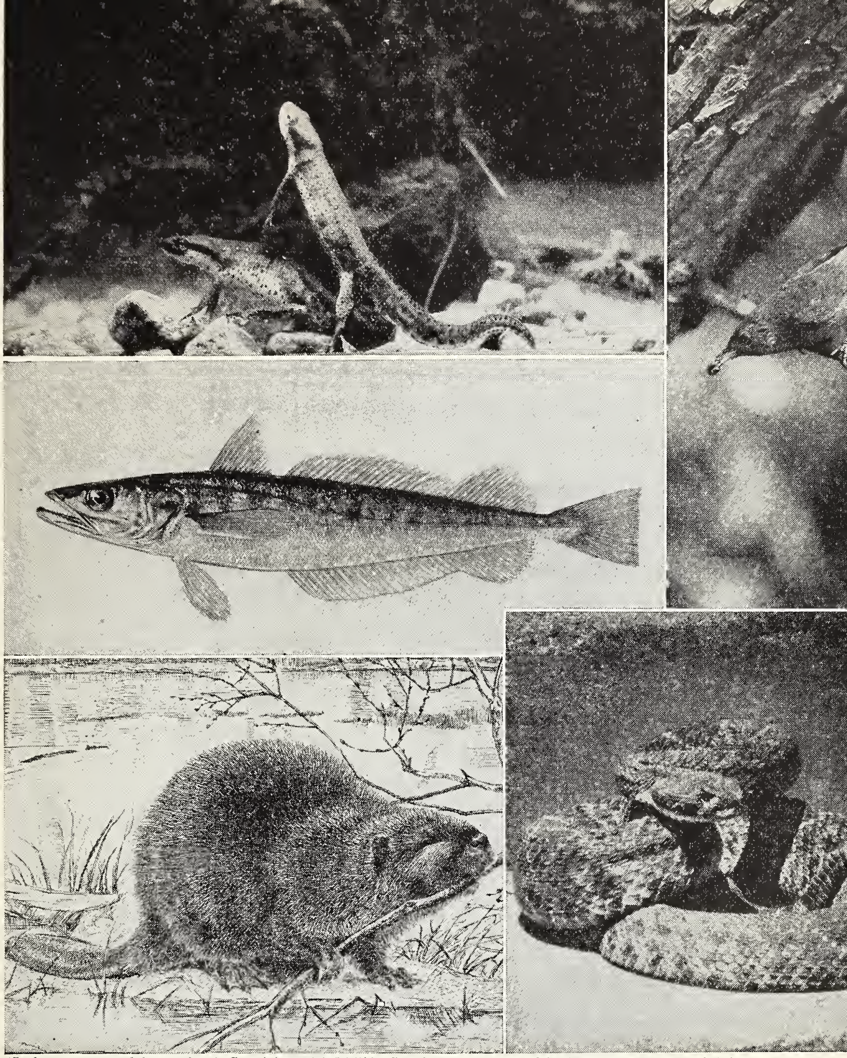
Most of the common large animals are those with backbones. They are classified together in a group called the vertebrates. Three of the five classes in this group are cold-blooded, and two are warm-blooded. The cold-blooded animals—the fishes, reptiles, and amphibians—are not really cold-blooded, but instead have the same temperature as the surroundings. Their blood may be warm or cold, depending upon the weather. The warm-blooded animals always maintain the same temperature, which for most animals is about 100 degrees Fahrenheit. Birds ordinarily have higher temperatures than do mammals.

All vertebrates have skeletons inside the body, with the backbone serving as the main structure upon which the body is built. Most vertebrates have four appendages—wings, legs, arms, flippers, or fins. A well-developed head is characteristic. In the head are the brain and special sense organs of hearing and sight.

What kind of animals are fish? The fish are vertebrates which live in water and breathe by means of gills. They are usually covered with scales, and their limbs are in the form of fins. Most fish have an air bladder, which is a sac found in the upper part of the body. The bladder can be made larger or smaller to keep the density of the fish about the same as that of water. Changing the size of the bladder permits the fish to rise or sink. The bodies of fish are streamlined for easy motion through the water. The tail is the chief organ of locomotion, for the other fins are used chiefly for balancing.

What animals lead a double life? Because frogs and toads live part of their lives in water and part on land, they are given a class name, amphibian [ăm·fĭb′ĭ·ăn], which means double life. Other amphibians are lizard-like in appearance, and include the newts and salamanders. The amphibians develop in water, and during the early stages of their lives breathe by means of gills. In their adult stages they live on land, although they usually remain near water. The adults have lungs and a heart, consisting of three chambers. Except for a few tropical species, they all have four legs. They never have scales. The mud puppies and salamanders have tails, while the frogs and toads do not.

Frogs and toads have short front legs, adapted to support their bodies, and long hind legs,



(Left, center, and bottom) U. S. Fish and Wildlife Service. (Top left) Hugh Spencer. (Top right) L. W. Brownell. (Bottom right) Sharp and Dohne

These five animals represent the five large groups of vertebrates. The newts (*top left*) represent the amphibians; the whiting (*center left*) represents the fish; the beaver (*bottom left*) represents the mammals; the wren (*top right*) represents the birds; and the rattlesnake (*bottom right*) represents the reptiles. Unrelated animals which live in the same environment sometimes are similar in appearance. How does streamlined shape help each animal shown?

L. W. Brownell

The Gila (hē′lȧ) monster is the only poisonous lizard in the United States. Its skin looks as if it were made of brilliant beadwork, serving as a warning coloration.

used for leaping on land and swimming in water. The toes of frogs are webbed.

Frogs usually live in or near water, but toads may live anywhere on land, returning to the water only to lay eggs. The frog feeds in the daytime, but the toad feeds at night. Both eat insects which are caught by a long, sticky tongue fastened at the front of the mouth. The frog has teeth in the upper jaw, but the toad has none. The frog has a smooth skin, while the toad has a rough skin.

The males of both frogs and toads can croak. Most amphibian songs are given when the animals are at the water to lay eggs, although the tree frogs sing among the branches of trees all summer. The sounds are produced when air passes forcibly back and forth between the lungs and mouth and over the vocal cords. Air in the mouth is held in sound sacs located either on the side of the head or under the throat. These sacs expand greatly when filled with air.

What kinds of animals are reptiles? Some of the reptiles are quite familiar. The snakes, turtles, lizards, crocodiles, and alligators are known at least by reputation to most of us. Reptiles are covered either with scales or with horny plates. They always breathe by means of lungs. When they have toes, the toes have claws. The reptiles on the earth today are not important compared to the giant reptiles of millions of years ago. In those days some could fly, some were huge and fierce land animals, and some lived in water. But reptiles could not adapt themselves to the changing environment, and few remain today.

A lizard has a long body supported upon four legs nearly equal in size, and some have a brittle tail which is easily broken off. Some familiar lizards are the horned toad; the chameleon [k*ȧ*·mē′lė·*ŭ*n], which can change its color; and the Gila [hē′l*ȧ*] monster. With the exception of the Gila monster, lizards are chiefly harmless, and are of value because they eat insects.

The snakes are the only land vertebrates which have no legs. Their ribs and the scales on their bodies permit them to move forward on rough surfaces at a considerable speed. Except for a few poisonous varieties, snakes are beneficial animals, for they eat insects for food. The stories you hear about snakes milking

cows, breathing poison, charming birds, and rolling like hoops are purely superstitions.

The turtles are protected by their hard shells, and as a result are slow-moving and awkward. Some turtles are vicious and for this reason should be treated with respect. Turtles have no teeth, but bite by means of a horny jaw.

The head of the crocodile is longer and more pointed at the snout than is that of the alligator, which has a broad head rounded at the snout. Otherwise they are rather similar in appearance and habits.

Most reptiles lay eggs, but a few bear their young alive.

What sort of animals are birds? Birds are animals with feathers. The legs of birds are scaly. The forelimbs are developed into wings which are used for flight by most birds.

The power of flight makes birds different in their habits from other animals. They can range over a larger area for food, and can protect themselves by escaping from their enemies. Their easy means of movement permits them to feed on the ground and to nest in trees. Flight makes possible the migration of birds, which makes them less dependent upon adaptation to cold than are the other vertebrates.

Some birds, however, are adapted to live throughout the year in one locality. These resident birds depend upon types of food available in winter as well as in summer. We see some birds which come north in summer, other birds which come south in winter, and still others only when they migrate in the spring or fall. Most of the familiar, insect-eating birds are summer birds. The English sparrow, a seed-eating bird, is a resident bird, for it stays throughout the year. The Arctic tern is the champion traveler, for it migrates almost from pole to pole.

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The bat and the mole both look somewhat like mice, but neither is a mouse. Bats catch insects in the air. Moles live underground and eat grubs.

The beaks of birds are adapted in various ways to getting food. Modern birds do not have teeth, although some ancient birds did. The mouth opens into a food tube which widens out into a

crop in which food is stored. The stomach of common pigeons and of some other birds consists of two parts: one of which secretes a digestive fluid, the other of which is a muscular gizzard filled with small pebbles used for grinding the food. Digestion is completed in the intestine.

All birds develop from eggs. Eggs commonly are incubated or kept warm by the female bird, although this is by no means always true.

What adaptations do mammals have? The mammals are unusual in many ways. They include the most intelligent animals. Mammals are the only animals which have hair, and the only animals which produce milk to nourish the young. The young of most mammals are born alive and, in general, require the type of care which can be given by an animal of a fairly high degree of intelligence. Man, of course, is the highest type of mammal.

The variety of adaptations of mammals is rather amazing. The bats are adapted to flight, while the porpoises and whales are adapted to a life in water. Most mammals, however, are land animals.

The mammals which carry their young in pouches include the kangaroos and the opossums.

The animals which have claws include three very important groups—the meat eaters, the bats, and the rodents. Meat eaters have sharp teeth, small digestive systems, and are powerfully muscled for their size. Dogs, cats, bears, and weasels are typical of the meat eaters. The rodents include the gnawing animals with chisel-like teeth. The common rodents are squirrels, rats and mice, beavers, and rabbits. Various rodents are adapted to different environments—in water, in trees, and on the ground.

The primates have nails instead of claws, and include monkeys, apes, and man.

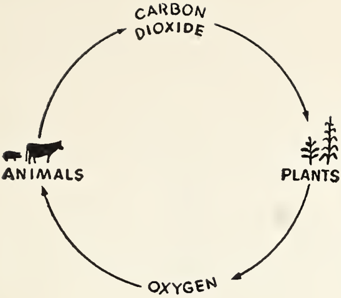
Another large group of mammals includes those animals with hoofs—pigs, deer, sheep, horses, and cattle.

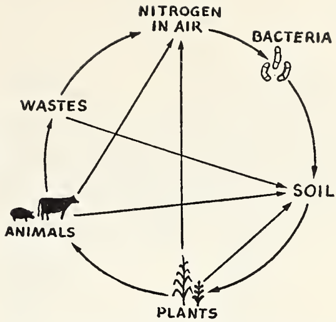
You can readily see that these animals are adapted to different types of lives according to their structures. Claws are not so well adapted for running long distances as are hoofs. Hoofs are of little value for digging or for climbing trees. There are equally important differences in teeth, digestive systems, methods of adapting to warm and cold weather, and other matters essential for survival.

Exercise

Complete these sentences:

Fish, reptiles, and amphibians are —1— blooded. Animals with scales are —2— or —3—. Most vertebrates reproduce by means of —4—, the exception being the —5—, most of which bear their young alive. Animals with hair are —6—. Most vertebrates have four —7—. The only vertebrates with true wings are —8—. Turtles are members of the group called —9—. The word —10— means double life.





The carbon and oxygen cycle (*left*) is much simpler than the nitrogen cycle. To help you understand the nitrogen cycle, look at the animals. Arrows indicate that they give off nitrogen through wastes and that when they die they give off nitrogen to the air or to the soil. Can you explain each arrow?

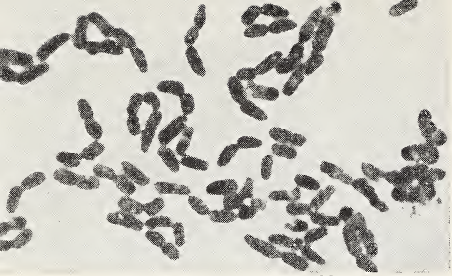
9. How do living things depend upon each other?

In our everyday observation we have learned that living things do not exist alone nor separately in the neatly classified groups which we have just studied. In any community of living things there are many different kinds of plants and animals, each depending in many ways upon other organisms. Some animals depend upon plants for food, some upon other animals. In less obvious but just as important ways, plants also depend upon animals for their food. Then too, maintaining the supply of air required by living things is dependent upon the different needs of plants and animals for gases in the atmosphere.

How is air kept in balance? When plants make food, they use some of the small supply of carbon dioxide in the air as a source of carbon. The carbon is stored in the plant. In the process of photosynthesis some of the oxygen stored in carbon dioxide is released and passes into the air from the plant.

An animal requires oxygen to release energy from food. The oxygen used in the body of an animal combines with the carbon and forms carbon dioxide. This gas passes into the air from the animal's body. Thus when plants make food and when animals use this food, they keep the supply of oxygen and carbon dioxide in circulation and available for continued use.

The plant also uses some of its food to release energy, which keeps its protoplasm in motion and makes its tropisms possible. In the process some of the stored food is oxidized, and carbon dioxide is released. Bacteria which cause decay also release the carbon stored in plants, for one of the products of decay is carbon



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These are some of the bacteria which live in the soil and fix nitrogen from the air in salts which are useful to green plants.

dioxide. Some carbon is permanently deposited by living things in limestone and other rocks and in coal. The changes just described are called the carbon dioxide-oxygen cycle.

How do living things use nitrogen? There is an abundant supply of free nitrogen in the air, but this nitrogen is of no use to the common plants and animals. They must take it directly or indirectly from the soil. There are few ways in which the supply of soil nitrogen is kept up. Some nitrogen is combined with oxygen in the air as a result of lightning discharges, and the resulting gas dissolves in rain water and enters the soil.

But the most important source of nitrogen from the air is that fixed in the soil by bacteria. These simple bacteria often live on the roots of the legumes—beans, peas, clovers, alfalfa, and locust trees—where they receive certain foods from the plants, and in return provide the supply of nitrogen so essential to this group of plants. Other nitrogen-fixing or nitrifying bacteria may live in the soil without the aid of the legumes.

The only source of protein foods [foods containing nitrogen] available to animals is plants. Although animals make more complex compounds of nitrogen than do plants, they still must obtain the raw materials indirectly from the soil.

The nitrogen used by animals is returned to the soil in two ways. The animals give off nitrogen in their body wastes. These wastes enrich the soil to an important extent. Farmers recognize this fact when they use barnyard manure for fertilizer. Then when the animals die their bodies decompose, forming certain nitrogen compounds, and some of the materials thus formed enter the soil. But because nitrogen compounds are easily dissolved in water, the supply may be washed out of the soil. Then too, there are certain bacteria which break up the nitrogen compounds formed by animals and permit the nitrogen to pass back into the air. When plants die, the nitrogen they contain may similarly be released—either to the soil or the air.

The nitrogen cycle is much more complex than is the carbon dioxide-oxygen cycle. But it is just as important for life.

What is a living community? A community of living things is an area with similar conditions of soil, moisture, and temperature in which many organisms live together. It consists of seed

U. S. Bureau of Entomology and Plant Quarantine

Three of these four animals—the walking stick (*top left*), the measuring worm (*top right*) and the viceroy butterfly (*bottom left*)—are fakes, seeming to be that which they are not. The monarch butterfly (without bars on the wings) is protected by bad taste. An animal which as learned by experience not to eat the monarch will not eat the viceroy. But if the wings of the viceroy are removed, the animal will then eat it.

plants large and small, fungi, algae, insects, worms, mammals, birds, and all the other kinds of living things which are adapted to that particular environment. A community may be a small area of swamp around the edge of a pond, or it may be a forest or

desert area extending for miles.

The living things within the community determine to some extent the nature of that community. When trees grow large they shade smaller plants and change the nature of the animal population which depends on plants for food. If the trees are killed by fire, a different type of community will appear. Of course a fire changes the nature of the soil as well as the type of plant which is left to develop. A plant or animal disease sweeping through a community may change the community balance in many ways.

Within the community are many organisms which are dependent on each other. For example, the gray green patches on rocks are called lichens. Once it was thought that they were single plants, but use of the microscope shows that they are colonies of algae and fungi living together. The fungi seem to absorb moisture which they release to the algae. The algae make food, some of which is used by the fungi. Both members of the partnership seem to be benefited, for the lichens grow where neither algae nor fungi can survive alone.

Ants live in many types of communities. Each species of ants needs certain kinds of food and certain conditions for nest-building. Some species of ants cannot do any work except fighting. These ants capture other ants which do the work of providing food and caring for the nest. Some soldier ants are so helpless that they cannot even feed themselves. Another group of ants cares for aphids, which give off honeydew. The ants of one species carry to the roots of corn plants the aphids which suck juices from the roots, injuring the plants. This removal of the juices may reduce the yield of corn and interfere with the food supply of animals which eat corn —man and his domesticated animals.

Many bacteria are dependent upon other living things for food. These parasites usually do nothing in return for the food they take, and if they are too numerous they may kill the plant or animal upon which they grow.

Saprophytes are somewhat useful, for they cause the release of carbon dioxide from dead plants which are keeping carbon out of circulation. Although saprophytes do cause food to spoil and useful materials to decay, nevertheless, in the whole community of living things, their work is essential for life to continue. For it must be remembered that no living thing owns the material of which it is made. Rather, it has merely borrowed the material for use and must return it if life is to continue.

DEMONSTRATION: DO SOIL BACTERIA GIVE OFF CARBON DIOXIDE?

What to use: Two flasks or milk bottles, one-hole stoppers to fit, glass tubing, limewater, cloth, string, garden soil, ink.

What to do: Put an inch of limewater in the bottom of each bottle.

Connect the two stoppers with a piece of glass tubing bent in a U shape, and in the center of the tubing put a few drops of water colored with ink. In one bottle hang a bag of moist garden soil, and insert the stoppers in the bottles. Observe for several days.

What was observed: How does the limewater appear in each bottle? Which way does the drop of water move in the glass tube?

What was learned: How do you know that bacteria produce changes in soil? What was the change noted? Which bottle was a control?

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: carbon dioxide, oxygen, nitrogen, air, legumes, manures, animals, plants, bacteria, food, decay, nitrifying. *Illustrate your paragraph by drawing in your notebook the two cycles discussed in this problem.*

10. Why is there a struggle for survival?

One of the important means by which any kind of living thing maintains itself is by its ability to produce many offspring. Some common weeds bear thousands of seeds. A single plant may produce seeds enough to cover a city lot with plants if all the seeds grew. Insects produce hundreds of eggs. Even the mammals can produce many young. One cow may have six to ten calves in her lifetime. A pheasant hen lays perhaps 20 eggs every year. The female fresh-water perch [a fish] lays 100,000 eggs each spawning season. Practically every living thing is similarly capable of producing more offspring than can survive.

What is overproduction? Because there is overproduction of all living things, they crowd and compete with one another in many ways. The most serious problem, of course, is that of finding a supply of food. Plants require a certain amount of space for their roots, and from the soil they take the water and minerals available. Soil simply does not contain enough minerals and water to support an unlimited number of plants. And in places where the soil is thin and dry, the amount available for plants is decidedly limited.

Even where the soil is rich and moist, there may exist such serious overcrowding of plants that there is not enough light to permit all plants to grow vigorously. Of the many seeds that may germinate, many will die before they mature because they are overshadowed by more vigorous or better-adapted competing plants.

There is a similar overcrowding of animals. If in a given area all the rats born as offspring of one pair should survive, the resulting rat population would soon overrun the land. In some tropical islands rats have been introduced by accident where they had no enemies to keep them in check. First the rats ate the best


Ewing Galloway

It may seem that lions kill because they are cruel. But the lion indirectly improves the animals on which it preys by eating those which are less able to escape. The lion kills, of course, to obtain food.

food available—birds' eggs, young, tender plants, and shellfish that they found at low tide. The lack of birds gave insects an opportunity to multiply, and the amount of plant growth was decreased. As the rats became more numerous, they began to eat the larger plants. The larger animals died from lack of food, and the rats ate their bodies. Finally, the rats ate everything that was fit to eat, and turned on each other. They soon starved, and the soil eroded. What once was a pleasant land at last became desolate waste.

This illustration is but slightly more extreme than many others that might be chosen. The importation of rabbits in Australia caused a large part of the continent to be overrun by the pests. Hundreds of thousands of dollars are spent in fighting them annually—by building rabbit-proof fences and by poisoning them. Foxes were introduced to help control the rabbits, but the new environment proved so favorable for the foxes that they became large and fierce enough to kill and eat sheep.

These examples are but a few of the many that show what happens when the balance of nature is upset by overproduction. Natural conditions may eventually


National Association of Audubon Societies

Not all living things are adapted to changing environments. This famous picture of the passenger pigeon shows these beautiful birds as they were painted long ago by Audubon. Today there is not a living passenger pigeon in the world.

restore any upset of balance in one of several ways.

How is a natural balance maintained? The term balance of nature refers to the constant shifting of the numbers of each kind of living thing around an average number. While the number of one kind of animal may be greater one year and smaller another, forces in the environment tend to restore these numbers to the average. A year that is favorable to one kind of living thing may be unfavorable to other kinds, and as a result there will be an increase of one kind and a decrease of the other.

Another factor affecting the number of a certain kind of living thing surviving is natural enemies. These enemies may be

From the Columbia picture "I Married Adventure"

This young gorilla has hands which are adapted for grasping.

larger animals or they may be parasites and disease bacteria.

The smaller animals—the rodents, the birds, and even the insects—are kept in check because they provide food for larger animals. Whenever their number increases, they provide an increased supply of food for the animals which naturally eat them. These animals, called predators, increase in number and reduce the population of small animals.

Another important factor in reducing numbers is disease. When animals are few in number, they stay far enough apart that the probability of infection is decreased. But when they live crowded together, the ticks, mites, and lice which carry dis-

ease can more easily pass from one animal to another. The catching of disease by direct contact is also more probable when animals are crowded. The increase in number of grouse, rabbits, and some other small animals proceeds in a regular manner, until finally they become seriously overcrowded. Then within a single year the population will drop to less than one-tenth of what it was. This change in the number of small animals is so regular in occurrence that game wardens can predict it quite accurately in some sections of the country.

The lack of food is an important factor limiting the number of survivors. When deer become too crowded in a forest, they eat leaves from trees and shrubs as far as they can reach. Young deer are unable to reach enough leaves for food when they no longer take their mothers' milk. They either grow up lacking in strength and vitality or die.

Another factor in keeping down populations is rate of reproduction. Only healthy and well-fed animals reproduce at a normal rate. When disease and a decreasing food supply reduce vitality, fewer young are produced, and the species tends to decline in number. This rule has been tested experimentally on fruit flies (sometimes called vinegar gnats) and is observed to apply to rats and domestic cattle.

Changes in weather from year to year affect the balance of living things. Moist years favor the growth of certain plant diseases, and are unfavorable to growth of some plants. Thus an unusually wet year may result in a decrease in some kinds of plants, and will favor those which grow well in moist weather and have few diseases. Such game birds as pheasants, quail, and ducks have difficulty hatching young in wet weather.

What is "survival of the fittest"? Among all types of animals there are differences of many kinds. These differences between individuals of the same species are called *variations.* Some animals are stronger than others, some more able to resist disease, some more capable of finding food, some more clever in escaping enemies. Some plants are able to send their roots deeper into the soil, some to climb higher to reach light, some to produce thicker foliage to shade competing plants.

In any given environment some individuals are better fitted to survive than others as a result of these variations. As is natural, these are the individuals that produce the most offspring and, as a result, their qualities are passed on to their offspring. Over a long period of time considerable changes may take place in a species. For example, all wild horses in the western United States are descendants of horses brought by the Spaniards. These horses were Arabian stock—tall, slender, and swift. But as a result of selection, their descendants are shorter, stockier, and tougher

U. S. Bureau of Animal Industry

These pups are busy taking in food in order to change it to protoplasm. Without food they could not grow up to become big dogs.

in ability to withstand cold and lack of food. The Indian pony weighs several hundred pounds less than its Arabian ancestors.

This natural selection of individuals results eventually in survival of the fittest.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: PLANT OR ANIMAL, NATURAL FOOD, NATURAL ENEMIES, USUAL ENVIRONMENT. *Using all information you can find in this entire chapter, complete the table by listing* rabbits, pheasants, deer, bear, frogs, mushrooms, ground squirrels, clover, crayfish, ducks, sparrows, and grasshoppers *in the first column, and other information in the other columns.*

A review of the chapter

Animals are adapted for survival by possession of structures and types of behavior suited to the environment in which they live. They solve their life problems in many different ways, but all have the same problems of reproduction, food-getting, metabolism, movement, and defense. Green plants are the only living things able to manufacture their own food, and all other living things are dependent upon them for a food supply.

The structures of plants and animals vary around a few basic plans. Plants or animals which are similar in most respects are classified together. The basis of classification is structure.

Living things cannot exist alone, for they depend upon each other for food and air. Nor can they exist when there is too much competition for food, space, and other

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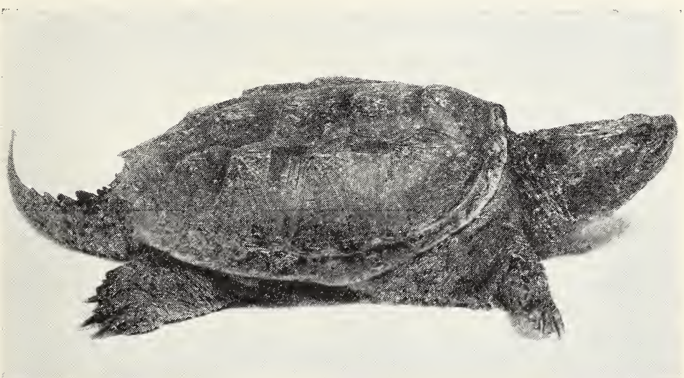
Only seed plants bear flowers. The apple blossoms are the type of flower which we commonly refer to as being typical flowers, but the pussy willow is just as truly a flower as the other.

needs. The greatest good results when a community of living things is in balance—that is, when various kinds of plants and animals live in numbers sufficient that many members of each species can survive, and no species exists in numbers sufficient to destroy its own food supply. The natural selection of individuals and species results eventually in survival of the fittest.



U. S. Fish and Wildlife Service

The snapping turtle has two effective defenses: a hard shell and the ability to bite viciously. Its disposition matches its ugly appearance.

List of words for study

adaptation	reptile	diffusion	chlorophyll
nucleus	overproduction	saprophyte	fungi
irritability	environment	arthropod	cambium
mammal	tissue	community	thallus
transpiration	stimulus	vertebrate	crustacean
osmosis	tropism	metabolism	amphibian
parasite	photosynthesis	lichen	nitrifying
mollusk	algae	instinct	variation
appendage			

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. The cell is the unit of structure and of function in all organisms.

B. Life is a series of chemical changes which take place in protoplasm.

C. The energy of living things which is released by oxidation of food originally came from the sun.

D. In the presence of light, green plants convert carbon dioxide and water into sugar, give off oxygen, and thus directly or indirectly produce all food.

E. Structure of an organism determines in what environment it must live.

F. All living things are able to respond to stimuli in the environment.

G. Growth is an increase in size or in complexity of parts of an organism.

H. Circulation of liquids in all organisms depends to a large extent upon osmosis.

I. Dependence of plants and animals upon each other for food and good living conditions tends to produce a balance of nature.

J. All living things start life from a one-celled stage.

List of related ideas

1. Algae absorb water containing minerals through their cell walls.
2. Metabolism includes the process of breaking down food to release energy in the cells.
3. Algae increase in number by cell division.
4. Although some molds cannot live in sunlight, they depend upon the sun for energy.
5. Bacteria make plant food available by causing decay.
6. In order to get light, grapevines must be supported by their twining tendrils.

7. Plants give off carbon dioxide when they use the food they make.
8. Many reptiles which once required a warm climate are now extinct.
9. An adult insect has many parts not found on the larva.
10. There is a constant streaming motion in protoplasm.
11. Animals require nitrogen compounds to build protoplasm.
12. Water passes from leaf veins through the cell walls into the cells.
13. Saprophytes live on decaying organic matter.
14. Nest-building is instinctive with most birds.
15. Fertilization brings together the two cells which start new organisms.
16. Legumes will grow best in soil in which there are nitrifying bacteria.
17. Larger organisms grow by cell division.
18. Leaves of plants often turn and follow the sun.
19. Air and water are essential materials for food-making by plants.
20. The fundamental life processes are carried on in cells.
21. Water enters root hairs from the soil.
22. A lichen consists of two plants living together.
23. A plant usually weighs thousands of times more than the seed from which it forms.
24. Photosynthesis is the process of manufacturing food by green plants.
25. Fish have an air bladder and fins to maintain their position in the water.
26. In an egg there is a single fertilized cell which is alive.
27. The turning of a vine stem around a support is a tropism.
28. One-celled plants increase in size after they are formed by cell division.
29. All living things are made of the same basic material.
30. The roots of plants grow toward moist soil.
31. As a pond dries up, organisms which lived there disappear and new organisms appear.
32. Without animals plants could not obtain carbon dioxide from the air.
33. A ground squirrel has claws adapted for digging burrows.
34. Root hairs contain a sirupy sap, denser than water.
35. Bacteria and molds do useful work in causing decay of dead materials.
36. A change in the amount of vegetable matter in the soil causes a change in the type of plants growing there.
37. Plants cannot manufacture food in the dark.
38. Food must be digested before it can be used.
39. Some young birds do not have feathers.
40. All animals finally depend upon green plants for food.

Some things to explain

1. Why do insects occupy such a prominent place among living things?
2. Why is it sometimes difficult to determine whether a certain organism is a plant or an animal? Does this difficulty extend to large, complex organisms?

3. How does all life depend on the work of chlorophyll?
4. Explain how some common plant or animal not mentioned in the text is adapted to its environment.
5. Explain how some plant or animal is dependent on other living things.
6. What advantages does the possession of a backbone give an animal over one that does not have a backbone? Why are there fewer vertebrates than insects?

Some good books to read

Buchsbaum, R. M., *Animals Without Backbones*

Carrigher, S., *One Day at Teton Marsh*

Carrigher, S., *One Day on Beetle Rock*

Clark, A. H., *Animals Alive*

Harpster, H. T., *Insect World*

Hegner, R. W. and Hegner, J. Z., *Parade of the Animal Kingdom*

Morris, P. A., *Boys Book of Snakes*

Novikoff, A., *Climbing Our Family Tree*

Platt, R., *This Green World*

Reed, W. M. and Lucas, J. M., *Animals on the March*

World Book Encyclopedia

Zim, H. S., *Mice, Men, and Elephants*

Zim, H. S., *Plants*

CHAPTER

12

Conservation of Living Things

The conservation of living things is part of the larger problem of conserving all natural resources. If our farm crops yield large returns, less land need be cultivated, and more soil can be left in its natural state. If we build our houses of semipermanent stone and concrete, the supply of trees will last longer. If we conserve our soil, our food supply will be better and more certain.

The conservation of wildlife depends upon maintaining clean streams, wooded areas, and good plant cover. Conservation of farm crops depends in part upon protecting them from their natural enemies. The rats of the United States eat about as much food as is produced on the farms of an average state. Insects, plant and animal diseases, and fire and flood destroy large parts of our food supply.

Improvement of our farm animals and crops assures better use of the returns of our soil. A hen which lays 40 eggs a year eats almost as much food as does one which lays 200 eggs. A scrub steer eats almost as much as does one which will produce twice as much meat. Just as much work is required to plant, cultivate, and harvest a poor crop as a good one.

Some activities to do

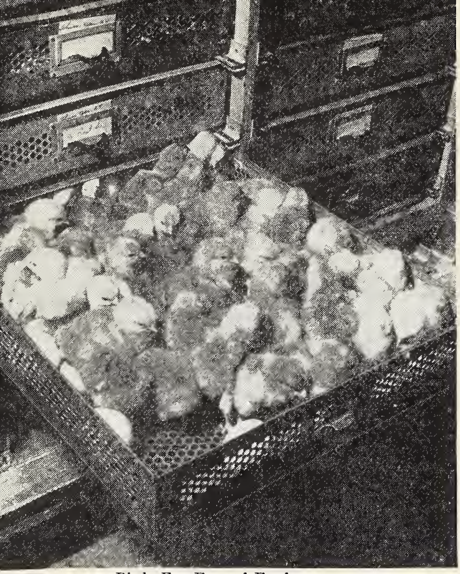
1. Obtain several different kinds of flowers and locate the various organs discussed in this chapter.

2. Start some houseplants in your home. Bulbs are especially easy to grow.

3. Make a collection of 25 useful plants and plant products grown in your community.

4. Make a collection of definitely harmful insects. Prepare with it an explanation of the harm they do.

5. Make a model of a flower, showing details of the ovary, using soap or a candle, wires, and cardboard.



Birds Eye Frosted Foods

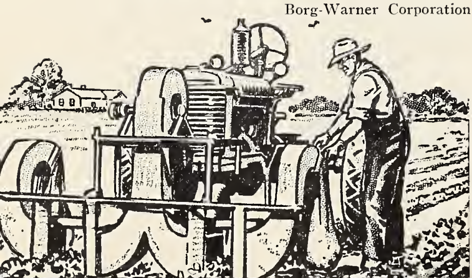
These downy chicks are just hatched. The tray is a small part of a modern incubator.

6. Collect leaves of 10 trees and make leaf prints. Put them on a card or poster, properly labeled.

7. Report on how game department officials decide what kind of fish to put in a certain lake. Learn how a fish census is taken.

This "bug catcher" attached to the front of a tractor uses a blast of air to blow insects off the plants and to pack them into bags.

Borg-Warner Corporation



8. Make a report on one kind of game or fur-bearing animal. Include information as to its value, its breeding habits, its natural range, its food, and its chances for survival.

9. Visit the best farm in your community, and write a complete report on the reasons it is best. Also, see whether you notice chance for still more improvement. Your county agent will help with information. If you live in a city, visit a greenhouse instead.

10. Make a bird chart by keeping a record of the birds you have seen, where and when you saw them, and, if you saw them eating, what they ate. The birds may be identified by use of a bird book.

11. Make a successful trap for catching sparrows, rats, mice, or flies. See U. S. Department of Agriculture bulletins.

12. Locate in your community hillsides which should be returned to pasture or to woodland. Arrange to have the owners of these fields supplied with government bulletins on soil conservation. Work out a conservation program for the school grounds.

Some subjects for reports

1. The development of hybrid corn
2. Breeds of dairy cattle and their production
3. Breeds of beef cattle
4. New poisons for rats, insects, or nematodes
5. Crop rotation
6. Effect of Tennessee Valley development on wildlife
7. Methods of increasing yield of pastures
8. Breeds of goats and their uses

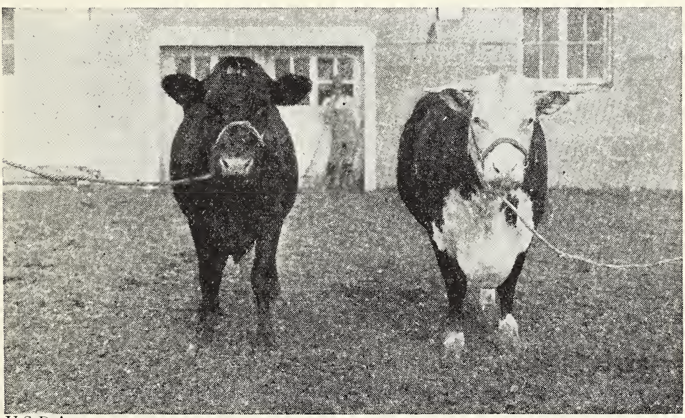
9. Deep freezing and storage of food
10. Forest conservation in your state
11. Methods of protecting and rearing wildlife in your state
12. Ratproofing buildings

1. How do we depend upon other living things?

Plants and animals provide most of our supply of food and clothing. They also provide many other things used in our homes and in industry. Yet of the thousands of common plants and animals, very few are of much direct use to us. It has been necessary to increase the number of useful plants and animals by domesticating many of them and to increase the yield of those which have been domesticated. We have also learned to protect those which are essential but not domesticated.

How are living things domesticated? Primitive people knew that some plants and animals were useful for food. Some of the useful animals could be tamed and kept in captivity. Some of the plants would grow under cultivation. But newly domesticated plants and animals were no better than the wild ones. The next problem was to select those which produced the most of the desired product. By careful selection of the best and by elimination of the poorer plants and animals, early herdsmen and farmers greatly improved their production.

Only when scientific knowledge developed was it possible to begin the improvement of farm crops and animals in a systematic



U.S.D.A.

While the beef animal at the right is no champion, it is far superior to the scrub at the left. The improved animal has a deeper, broader body than the other.

Wyoming Hereford Ranch

This Hereford bull is typical of the best animals of his breed. Such a sire would bring up the meat production of a scrub herd to a marked degree.

manner. By a process called hybridization [hī′brĭd·ĭ·zā′shŭn] it is possible to unite two varieties to produce a new combination of traits. By planned development of plants and animals with many desired traits it is possible to produce much more food than was possible by leaving the combination of desired traits to chance.

Increasing the yield of farms is very important. It is estimated that with present improved methods of agriculture about 2.5 acres of land per person are needed to provide enough food and clothing for healthful and comfortable living. The amount of good land now available on the earth amounts to about two acres per person. Many people live in want, and the population of the earth is still increasing. Lack of food leads to illness, starvation, and war.

How can we increase production? There are many reasons for increasing production of food. Soil is wasted if used to produce poor crops. The same amount of gasoline and wear on a tractor is required to cultivate poor crops as good crops. In addition to use of improved varieties of crops and animals, we can increase production by better cultivation and fertilization of the soil, by better control of insects and diseases of plants, by reducing waste and spoilage resulting from poor handling of crops, and by shifting from wasteful production to efficient production methods.

In the United States we have still enough farmland to provide food for all our own people. We now have about three acres of productive land per person. Obviously we must use this land carefully, for soil does not last forever. Improved methods of cultivation are just as important as improvement of livestock and crops today, and for the future more important.

What are the chief kinds of domestic plants? Two large groups of plants, the grasses and legumes, form the basis of modern civilization. The grasses include wheat, corn, oats, barley, rye, and other small grains, and the great group of pasture and hay grasses. Of these, more corn is grown in the United States than all other grains combined. Although corn yields starch, meal, cereals, oil, and sugar for human use, about 85 per cent of the corn crop is fed to livestock. Green cornstalks are cut up, put into tanks called silos, and fermented for livestock food, somewhat as cabbage is

U.S.D.A.

The best index of the breeding worth of a hen is the kind of offspring she produces. This White Leghorn (*left*) laid 290 eggs and had seven daughters that laid an average of 230 each. The Rhode Island Red laid 236 eggs and had five daughters that laid an average of 226 each.

made into kraut. Other plants—grass, alfalfa, potatoes—may also be stored in silos.

Wheat is our chief bread grain. Other cereals are used to some extent for foods for human beings but most of them are fed to livestock. The pasture grasses are our most important single source of livestock food. Much of the United States is fit only for grass or forest lands. In fact only 7 per cent of the land of the earth is now under cultivation. If grasslands are properly used they will yield food we cannot otherwise obtain at all. Pasture grasses can be used for production of dairy products, wool, and other animal products. In terms of our total food supply, it is poor economy to feed corn to cattle, for it requires seven calories of corn to produce one calorie of beef.

The legumes are plants which produce their seeds in pods and which contain more proteins than do most other plants. These plant proteins are not as good for human food as animal proteins, but do provide essential supplements to our animal foods. People of the crowded parts of the world, who cannot produce enough animal protein to survive, depend on legumes for food. Legumes include beans, soybeans, peas, peanuts, and the hay and grazing crops clover, vetch, alfalfa, and lespedeza.

Other common plant groups are the family which includes the potato and tomato, the familiar root crops, the cabbage family which provides eight useful food plants, onions, and the many fruit and nut trees. The most useful fruits come from three great groups, the citrus fruits, the stone fruits, and the rose family which includes pears and apples.

Cotton is our most important fiber crop, with flax next. The seeds of certain plants produce

M. Kettel

Among no other domesticated animal is there a greater variety of sizes and shapes than there is among dogs. Every breed of dog has its peculiar traits which make it different from others. At the top, the cocker spaniel (*left*) and the Scottish terrier; in the center, the fox terrier (*left*) and the Pekingese; and at the bottom, the German shepherd dog (*left*) and the greyhound. These dogs vary more in size than is shown in the pictures. Some of them could easily survive in the wild state, while others could hardly take care of themselves under favorable conditions.

oil and meal used for animal food. Linseed oil from flax is used in paint.

What are our most important farm animals? Cattle today are by far the most important animals grown on farms. They produce both meat and dairy products, and in addition provide most of the leather used for clothing. Next in importance are swine, for pigs produce meat more quickly and produce more meat on a given amount of food than do cattle. Cattle, however, can use pasture grasses and legumes to a much greater extent than can swine. Goats are becoming increasingly important as more people live in suburban areas and produce their own food supplies. Sheep produce wool which is still the best of all animal fibers for clothing. More people have poultry than any other kind of domestic animal, and 96 per cent of farm poultry is chickens. Horses and mules are still important in many areas, and many other kinds of animals are used for special purposes, such as for pets and for fur production.

Exercise

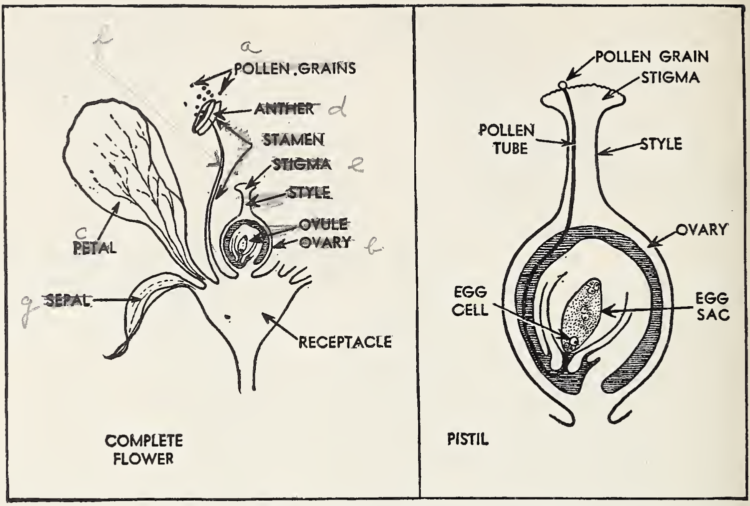
Make a table by ruling your paper into four columns. Head the columns as follows: SOURCES OF PROTEIN, SOURCES OF FATS AND OILS, SOURCES OF CLOTHING, ANIMAL FOODS. *In the correct column list the various crops and animals mentioned.*

2. What laws control improvement of living things?

When man first domesticated plants and animals, they were not of good quality. The flesh of swine was tough and strong in flavor. Cattle produced little more milk than was needed by the calves. Grasses produced only a small amount of seed.

The first attempts of farmers to improve their newly domesticated crops and animals were conducted on a trial-and-error basis. In spite of their lack of a scientific explanation of the working of heredity [passing traits from one generation to the next], they were able to improve some breeds of animals and some varieties of plants to a marked extent. But it was not until the discovery of Mendel's Law that the problem of improvement could be attacked in a scientific manner.

What are variations? Natural selection is based upon the fact that because of variations some individuals are better fitted to survive than are others. Variations consist of many specific differences in individual traits [qualities or characteristics]. For example, garden peas may be tall or short. Their leaves may be smooth or covered with tiny hairs. Their blossoms may vary in color. Their seeds may be smooth or wrinkled, and they may be yellow or green in color. Variations in these specific traits



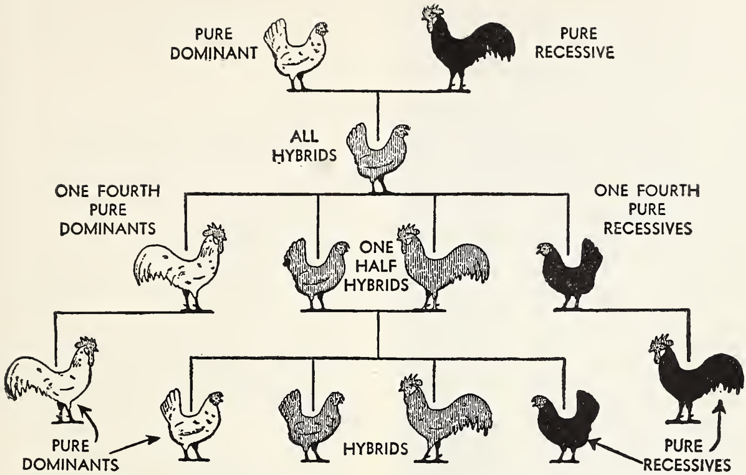
The essential parts of a flower, and the process of fertilization are shown in these diagrams.

added together make up the differences between individuals.

What experiments did Mendel do? Gregor Mendel was a European monk who was interested in gardening. He studied garden plants and discovered variations in their appearance. As a result of his observations, he carried on a series of experiments with garden peas.

Mendel knew that seeds are formed when pollen from one flower is placed on the pistil of another flower. Pollen is formed in a knoblike anther which grows on the end of a filament. The anther and filament make up the stamen, which is the male part of the flower. The seeds are formed in a space called the ovary, at the base of the pistil, which is the female part of the flower. The pistil has a sticky knob called the stigma, which is supported on a stalk called the style.

When pollen from one flower is put on the pistil of another flower of a different variety but of the same species, the process is called *crossing*. Mendel crossed tall garden peas—plants about six feet high—with short garden peas—plants about a foot and a half high. When the flowers on these peas were mature he carried pollen from the anthers of the tall pea and placed it on the stigma of the flower of the short pea. To prevent other pollen from falling on the stigma, he cut the stamens from the flower of the short pea and kept the flower covered with a bag. In a similar way he pollinated the flowers of tall peas with pollen from the anthers of short peas. In the fall he



Color is inherited according to Mendel's law. In this case the hybrids show blending of color. Most hybrids resemble the dominant parent instead of showing blending of characteristics.

saved the seeds and kept them through the winter.

When the plants produced by these seeds were mature, the peas were all tall. The shortness of half the parent plants did not appear at all!

These plants were in turn used in the experiment. Pollen from one tall plant was used to fertilize flowers of other tall plants. In this second generation both short and tall plants appeared. Careful count showed that there were three times as many tall plants as short plants. The shortness trait, in other words, reappeared in one-fourth of all plants produced in the second generation.

In the third generation the short peas were kept separate, and pollen from one short pea was used to fertilize the flower of another short pea. Tall peas were similarly kept separate. The short peas produced only short peas, but the tall peas also continued to produce some short peas.

After the first generation, there were three kinds of peas instead of two. There were some tall peas, which produced only tall peas. These are called pure. Other tall peas produced both tall and short peas. These mixed peas are called *hybrids*. Then there are the short peas, which are always pure because they produce only short peas.

It is possible to cross only closely related living organisms. In general no groups more distantly related than species within the same genus can be crossed.

What is Mendel's Law? It is not easy to state Mendel's Law. If you study the above diagram,

Francis M. Davis

This X ray of the flower angel's-trumpet shows stages in development of buds into flowers. Note also the veining of the leaves.

it will make the law simpler to understand. Dominant traits are those which appear more frequently than other traits. Those traits which appear less frequently are called recessive. The law may be stated thus:

1. When individuals having unlike traits are crossed, the offspring of the first generation will be hybrids showing the dominant trait.

2. When hybrids are used for reproduction, three-fourths of the offspring will possess the dominant trait, and one-fourth will possess the recessive trait.

3. All offspring possessing the recessive trait will breed true—that is, will produce only their own kind.

4. The offspring showing the dominant trait include two-thirds which are hybrids, and one-third which are pure dominants.

5. Pure dominants breed true.

The table on page 577 gives the results of the experiments which provide the basis for Mendel's Law.

What are some dominant and recessive traits? Dominant and recessive characteristics in other forms of life react in a manner similar to reactions in peas. For example, when a black and a white guinea pig are mated, all of the offspring of the first generation are black; that is, black is dominant and white recessive. In the second generation the pigs follow the same law as peas. There are three black pigs to one white. The white pigs always breed true, but the black prove to be of two kinds: one which always breeds black and another kind which produces black and white in the ratio of three to one.

What is incomplete dominance? As a general rule traits appear according to the law of

	PARENTS	
Tall peas (dominant)		Short peas (recessive)
	FIRST GENERATION	
	All tall peas (hybrids)	
	SECOND GENERATION	
Three-fourths tall peas; (mixed—dominant and hybrid)		One-fourth short peas (recessive)
	THIRD GENERATION	
	Short peas all give short peas (recessive) Pure tall (1/3) give tall (dominant) Hybrid tall (2/3) give 3 tall to one short (mixed—dominant and hybrid)	

complete dominance. Yet there are some instances in which the contrasting traits follow the law of incomplete dominance. For example, when red and white four-o'clock flowers are crossed, we get in the first generation neither red nor white flowers, but instead all are pink. If these pink hybrid flowers are used to pollinate each other and the resulting seeds planted, in the second generation colors occur in the ratio of one-quarter red, one-half pink, and one-quarter white.

The table on page 578 gives a few examples of dominant and recessive traits as determined by actual experiments.

Exercise

Complete these sentences:

Mating two individuals of the same species but possessing different traits is called —1—. The offspring of such a mating is called a

U. Atlee Burpee Company

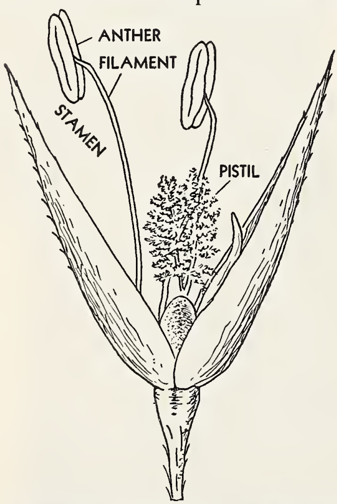
These marigold plants are covered with screens to protect them from insects carrying undesirable pollens. The instrument is used to detect odors, for the aim is to produce an odorless plant.

ORGANISM	DOMINANT TRAIT	RECESSIVE TRAIT
Cat	Black	Maltese
Dog	Gray	Black
Cattle	Black	Yellow and red
Horses	Black	Chestnut
Poultry	Black	Yellow
Cotton	Long fiber	Short fiber
Man	Brown eye color	Blue eye color
	Right-handedness	Left-handedness

—2—. The —3— produced by the stamen is placed on the —4— of a second flower in cross-pollination. The seeds develop in the —5—. Hybirds produce offspring, of which —6— resemble the dominant parent, and —7— resemble the —8— parent. Pure dominants breed —9—. The kittens of a pure black cat and a maltese cat would be —10— in color. If these kittens produced young, their color would be —11— and —12— in the proportion of —13—.

3. How does man control plant breeding?

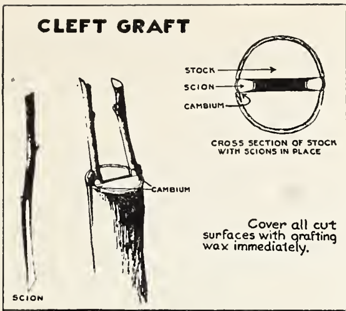
The discovery of the laws which control improvement of plants and animals makes possible many short cuts in producing new or better varieties of plants. Where before it was necessary to discover by experiment and trial and error what results to expect, it is now possible to predict quite accurately in advance what gains can be made from crossing different varieties of plants.

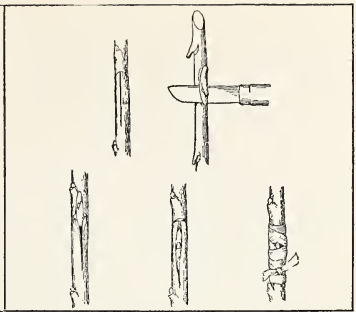


The essential parts of a grass-flower are the same as those of a showy flower. The leaves are scalelike, however, and because the flower is usually small, its parts are difficult to see.

Why is selection of plants important? Out of a field of thousands of plants, there may be only a few that have the qualities which are desired. One plant may be resistant to disease. Another plant may have good yield but may lack other desirable qualities. Before a program of plant breeding [mating and improvement of living things] is started, it is necessary to select the plants which have the traits wanted.

Sometimes no domesticated





U.S.D.A.

The two methods of grafting (*left*) and the method of budding (*above*) are the chief means of propagating fruit trees. The inserted branch or bud is taken from a tree known to bear good fruit. To experiment with grafting, practice with twigs and branches of worthless trees. Grafting should be done before sap flows in the spring.

plant has the desired trait. In such cases it is necessary to find a related wild plant and, by cross-breeding, combine its good qualities with those of the domesticated plant. A plant which will grow on a cold mountain may be crossed with a domesticated plant to make a new variety more resistant to cold than are our common plants.

Can man produce new types of plants? It is possible by crossing to produce plants with entirely new combinations of traits, but so far man has been unable to produce any plant with qualities which do not already exist in other plants. For practical purposes, the plants which are produced are new because they serve new purposes.

New varieties are produced by natural events by a process called *mutation*. The process is not well understood, but it is based upon new arrangements of protoplasm within the cells.

When a cell divides, the nucleus goes through a complex process of rearranging its parts. Inside the cell are tiny, thread-like bodies which are visible when strongly magnified at the time of cell division. Because these bodies absorb dyes when the cell is stained, they are called chromosomes [colored bodies]. These chromosomes are the devices which make possible the inheritance of specific traits according to Mendel's Law. When an ordinary cell divides, the chromosomes divide, so that each new

cell gets its correct number of chromosomes. These chromosomes vary in number according to the species. The pea plant has 14 and the corn plant 20.

When reproductive cells are formed, each parent cell loses half its chromosomes, so that each offspring obtains half its chromosomes from each parent.

Sometimes there is some accident at the time of cell division, when the male or female cells form, which changes the number of chromosomes. When this happens, we have a case of mutation —that is, a plant with entirely new characteristics appears. Sometimes these mutant plants die immediately, but sometimes they survive and breed true. Thus a new species is started. There has been discovered a chemical [colchicine] which when put on flowers upsets the normal division of cells, and mutants are produced more frequently as a result. Use of this chemical is rather recent, and it is not known how many unusual plants may eventually be produced by its application.

How are plants fertilized? When a grain of pollen falls on the mature stigma of a plant of its own kind, it sends a tube of watery protoplasm down the style of the pistil until it reaches the ovule or egg cell in the ovary. The protoplasm of the pollen grain forms a sperm cell which unites with the egg cell, and these grow as a single cell. When the union is complete, the cell divides, and new cells are formed. The embryo plant is surrounded by a supply of food, and all is enclosed in a skin or covering to form a seed.

How is pollination controlled? Under natural conditions pollen carried by insects pollinates showy flowers. The wind pollinates those flowers which are not showy. The means of controlling fertilization used by Mendel are still in use.

The plant breeder may remove the stamens of the flower to be pollinated and with a brush deposit pollen from another flower on the pistil of the first flower when it is ripe. To prevent pollen from being carried to the flower by a bee or by the wind, the flower is covered with cloth screens or a paper bag.

The grasses produce flowers containing the same essential parts that are found in showy flowers, but instead of having petals and sepals, the flowers of the grasses are enclosed in green, scalelike leaves. The flowers of grasses ordinarily grow in heads, and the individual flower is tiny. If they are magnified 20 times, they are as pretty as the more common flowers. Corn plants produce pollen in the flowers which grow at the top of the stem. These male flowers are called tassels. The egg cells are produced in the female flower, which is the immature ear. The pollen falls upon the silk of the ear, and fertilization takes place in the usual way.

What use is made of the new plants? When seeds are pro-

U.S.D.A.

The strawberry plant is capable of propagating itself by means of runners. As the new plant formed becomes well rooted, it is capable of carrying on its existence independently.

duced by crossbreeding, the process of introducing a new variety is far from complete. Crossbreeding increases the amount of variation in plants tremendously—that is, the offspring have combinations of specific traits different from those of the parents. Because of this, selection must be made with especial care, for a plant that looks good may have in it some definitely undesirable trait. A berry plant may produce large fruit of excellent flavor, growing on a large and vigorous bush, but the fruit may be subject to crushing too easily for practical market use. Such a plant may either be discarded or used for further crossbreeding, depending upon circumstances. Crossing produces a very small proportion of useful plants. For example, in one series of breeding experiments carried out in Maryland, 86,000 strawberry seedlings were raised, but of these only seven were of such desirable qualities that they were saved and named.

If a plant seems to have every desirable characteristic which the plant breeder is seeking, he then keeps it and very carefully observes its development. If it is a plant, such as wheat or corn, which is always produced from seed, the seed must be planted until enough is produced to put it on the market. It must also be watched to observe whether or not it will breed true and whether or not it has hidden but undesirable traits.

Few of the more successful present-day farmers produce

American Chemical Paint Company

Use of chemical hormones will cause roots to grow on softwood cutting of plants that will not root at all without the hormone. Such a plant is the arbor vitae shown. The two cuttings have each been in the rooting bed for five weeks. Only the one on the right was treated.

their own seed. Instead they buy it from breeders who carefully cross varieties to produce hybrids of known qualities. Tall corn is no longer grown because a lower stalk which produces more ears is easier to grow and the corn is easier to harvest either by hand or machine pickers. Hybrid grains usually yield considerably more profit than field-selected seed.

If the plant is one which is produced by means other than by seeds, enough plants must be produced to establish the new variety in quantities sufficient for marketing. It is expensive both to produce new plants and to advertise them to sell them for a profit.

How are plants produced when not grown from seeds? There are two ways of growing plants without use of seeds. One is to cause roots to grow from the stem of a desirable plant. The other is to join the stem of a desirable plant on roots of a less desirable plant.

Strawberry plants send out a stem from the parent plant. This stem, called a runner, puts forth roots and leaves where a joint touches the ground. Each joint eventually becomes a separate plant. Softwood cuttings are made by cutting off a leafy part of a growing stem, and planting it in water or moist soil. Hardwood cuttings are made by planting sections of stems without leaves. They are rooted in much the same way as are softwood cuttings. Grapes and currants may

be started from hardwood cuttings.

When a stem is buried while it is still attached to the plant, the process is called layering. New roots and branches appear at joints, and these new plants may be separated from the parent plant as soon as they are large enough and planted elsewhere. Raspberries and grapes may be started by layering.

The eyes of potatoes are buds, containing in undeveloped form both stem and leaves. When the eye is planted, it draws upon the supply of food in the potato until it gets a start and then develops roots from the stem.

It is possible to join a branch of one tree upon the stem of another in such a way that the branch will grow. This process is called grafting. Just inside the bark is the cambium layer. The cambium layers of the two stems must join. The simpler kind of grafting is accomplished by cutting off the stem of a tree and cutting a V-shaped notch in it. The branch is cut in the form of a wedge, and the two are carefully fitted together. Then the graft is wrapped with string and covered with wax to keep out decay. A more complex graft is called whip graftage, shown in the diagram. Grafting must be done when the wood is dormant—that is, when no sap is flowing in it.

A bud from one tree may be cut off and slipped into a T-shaped cut in the bark of another tree, and the bud will grow into a branch. (See page 579.)

Commercial florists speed the rooting of plants by applying to the stem a chemical hormone. There are two such chemicals in use. By using these hormones, the time of rooting can be cut in half, and some plants will form roots with the hormone which will not root at all without it. A hormone is a chemical which regulates growth or other life processes. Vitamin B_1 is used to promote the growth of roots after they form. Plants treated chemically may grow almost twice as fast as do untreated plants.

All these methods of propagating or producing plants are used when the seeds of the parent plants will not breed true. Most of our fruits, potatoes, and many flowering shrubs do not produce offspring like the parents from seeds. They can be produced only by one of the methods described.

The roots of European grapes cannot survive the parasites found in this country, and as a result such grapes are grafted onto the roots of wild grapevines. Another advantage of grafting is that more than one kind of fruit can be grown upon one tree. Several kinds of apples and pears will grow on a tree. Cherries and plums will grow upon the same tree. But the fruits must be similar in structure, or grafts will not thrive on one tree.

Exercise

Complete these sentences:

The essential parts of a flower are the —1— and —2—. The col-

ored, threadlike bodies in the cell nucleus are the —3—. These divide when the —4— divides. The —5— cells have only half as many of these as do other cells. The mating and improvement of living things is called —6—. Causing a branch of one plant to grow on the stem of another is called —7—. Strawberries reproduce by means of —8—. Union of egg and sperm cells is called —9—. Potatoes are grown from —10— called eyes and the potato is a —11—.

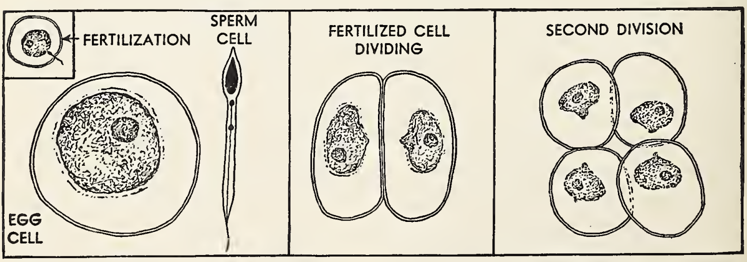
4. How does man control animal breeding?

The problems of the animal breeder are considerably different and in some ways more difficult than are those of the plant breeder. Our domestic animals in general reproduce slowly and produce few offspring compared to plants. First-quality farm animals are quite expensive, so that many farmers can scarcely afford the money required to invest in a herd of good animals.

But otherwise the problems are about the same. It is necessary to select animals with the desired characteristics and mate them to keep these traits or, by crossbreeding, to try to bring about more desirable combinations of traits already existing.

How do animals reproduce? As you know, farm animals are either birds or mammals. They are alike in that fertilization takes place in the reproductive organs of the female. The male produces sperm cells in organs called testes. The female produces egg cells in the ovary. When mating occurs, sperm cells are deposited by the male in a tube leading into the female's reproductive organs, and the egg and sperm cell unite. As soon as the mammal egg is fertilized, it produces around itself a thin membrane and attaches itself to the wall of the uterus—the organ in which development takes place.

The embryo takes its food from the mother by absorbing it from her blood stream. The blood stream of the embryo is not connected directly to the blood stream of the mother, but

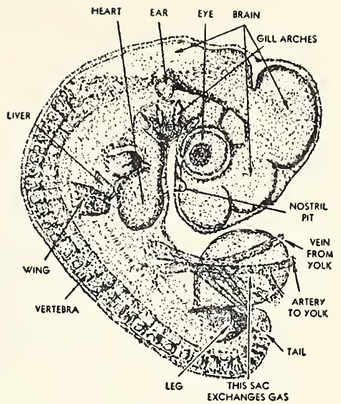


The egg and sperm cells combine to form one cell, which then grows and divides.

both are in contact with a membrane which separates them. The kind and amount of food available to the mother determines to a considerable extent the growth and health of the offspring. Thus it is important that animal breeders care for the female animals as perfectly as possible.

Female birds may lay eggs without mating, but the eggs are infertile—that is, they will not hatch. When enough fertile eggs are laid, the female bird sits upon the nest until they hatch. The usual number of eggs hatched by hens or ducks ranges from 10 to 15. Modern hatcheries do not employ hens for producing chicks, but instead put the eggs into incubators. The incubator is a box heated by electric coils or a lamp. The temperature is controlled by a thermostat, and the humidity is carefully regulated. The eggs must be turned daily to insure perfect development of the chick.

The chick develops from a single cell attached to the yolk of the egg. A system of blood vessels spreads through the yolk, and a tiny heart circulates blood to collect food from the egg and to get rid of gaseous wastes. A sac develops for the exchange of gases. Gradually budlike wings and legs appear, and the head becomes definitely recognizable. From this stage onward the embryo looks more and more like a chick, until at the end of 21 days the chick breaks its way from the shell. The chick has a horny knob on the top of its beak for



A chick embryo in an egg looks like this after four days of growth. It is not quite a third of an inch in length. The fully formed chick leaves the shell after 21 days of growth.

breaking through the eggshell.

What animals are commonly produced on farms? Practically all farmers who have cattle produce the calves on the farm. A calf may be used for veal at the end of six weeks, for baby beef at the end of six months, and for beef at the end of a year. A young cow ordinarily should bear her first calf at the age of 2 or 2½ years. A cow, of course, does not give milk until she has produced a calf, and a dairy cow continues to produce milk for 10 to 11 months after the birth of the calf. A beef cow gives milk enough for her calf and little, if any, more.

The usual farmer has only two or three horses and may not find it profitable to produce colts.

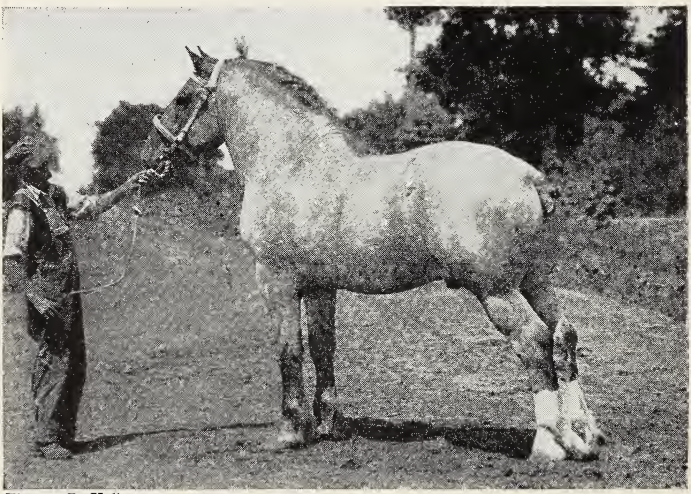
The ordinary male horses used for drawing wagons and for saddle use are not capable of repro-

NAME OF MALE	NAME OF FEMALE	NAME OF YOUNG	PERIOD OF GESTATION OR INCUBATION
Bull	Cow	Calf	280 days
Stallion	Mare	Colt	330 days
Ram	Ewe	Lamb	145 days
Boar	Sow	Pig	115 days
Rooster	Hen	Chick	21 days
Drake	Duck	Duckling	28 days

ducing because they have been operated upon to remove the testes. Steers and male pigs that are raised for meat similarly are not able to reproduce. The stallion, the bull, and the boar are likely to be vicious and difficult to handle. The meat of bulls and boars is tough and strong.

The above table includes the correct names of the different animals used for producing young on the farm and the amount of time required for the young to develop. The period of gestation is the length of time the young animal develops within the mother's body; the period of incubation is the amount of time the eggs require to hatch.

Why is the sire important? Purebred livestock—that is, animals which are of proved quality and of a certain variety—are expensive. Many farmers still have scrub livestock—animals which are of poor quality and of mixed ancestry. To improve a farm herd by selling the scrub animals and replacing them with pure-



Thomas R. Holbert

The Belgian breed of horses is one of the best draft breeds. Note the sturdy body, neck, and legs of this prize-winning stallion.

breds would cost thousands of dollars.

But instead of buying a whole herd, the farmer can buy a male animal—the sire—and produce offspring which have one purebred parent. One male mammal may produce 20 to 150 young a year, while one female can produce few young. Thus it is easily seen that the male becomes many times more important in improving the quality of the herd than any female animal can be.

If a farmer continues to use only purebred sires, he can gradually improve the quality of his herd until, for practical purposes, the animals are purebreds. The second generation of offspring will have three-quarters purebred qualities, the third generation seven-eighths purebred qualities, and the fourth generation fifteen-sixteenths purebred qualities. With cattle, this program will require a minimum of eight years; but with sheep, pigs, and chickens, it can be brought about in four years.

Are there hybrid farm animals? In general, crossbreeding is not considered a wise practice on the farm, except as already described to improve the quality of scrub herds. If a purebred Holstein dairy cow is crossed with a purebred Shorthorn bull, the calf may not have the desirable qualities of either parent. Livestock breeders are very careful to avoid crossbreeding in order to be sure of the quality of their livestock.

The mule is the only farm animal that is always a hybrid. The father of the mule is a jackass, a kind of donkey, and the mother a mare. The mule is not fertile—that is, it cannot produce colts—probably because the ass and the horse have differing numbers of chromosomes.

How are desirable animals selected? The test of a farm animal is its ability to produce. To select producing animals, various methods are used. In a flock of chickens some hens lay many more eggs than do others. The best way to separate these hens is to use trap nests in which the hen lays her egg. Each hen has a num-

The scales is the instrument needed to select a champion cow. This cow, Femco Alma, produced 12.5 pounds of milk in six hours. Registered cows are given names, and no other cow may be registered under the same name.

Minneapolis "Tribune"

bered leg band. When the hen is released from the nest, the attendant makes a check mark after her number. Hens which are not laying are thus easily detected. Hens can also be sorted out or culled by examining their body build. A poor layer has a poorly developed body. In one experiment with 75 flocks of hens, 4419 hens were chosen to be kept, and 3137 were to be rejected. Those which were to be kept in a test laid on the average 2018 eggs a day, while those which were to be rejected laid only 112 eggs a day.

There are two important tests of a dairy cow: the weight of milk given per day and the per cent of butterfat it contains. Then too, some cows give milk for a longer time than do others given the same care. The only way to measure the value of a bull in a dairy herd is to compare the milk-giving abilities of his daughters with the abilities of their mothers. If the average yield of the daughters is considerably in excess of the mothers, the bull has contributed something of value to the herd. A bull which looks good in the show ring may be of little value in herd improvement.

Pigs and beef cattle are judged by their ability to put on meat in proportion to the amount of food they eat. Horses are judged either by their speed in running or their strength in pulling. In the case of pigs, it is important to keep sows which produce large litters of pigs—10 or more being desirable.

Exercise

Write a paragraph summarizing this problem, using in the paragraph the following words: sperm, egg, gestation, stallion, sire, testes, ovary, selection, hybrid, mare, purebred, mule, improvement.

5. Does good care improve crops and animals?

The successful farmer selects crops and animals with good heredity and gives them good care. Both are important. The best care will not make a cow give large amounts of milk if she has not inherited that ability. Nor will the best cow give large quantities of milk if she is given poor care.

Agricultural experts estimate that the annual yield of corn in this country is decreased about one-third through failure to control such factors as poor seed, weeds, insects, plant diseases, and lack of sufficient moisture in the soil during the midsummer. The farmer can control these factors by proper selection of seed, rotation of crops, preparation of soil, and proper tilling of the land while the crops are growing.

Farm work consists of growing plants and animals. These two activities are often closely related because many of the plants raised are used to feed animals. The


Lone Star Cement Company

A modern barn is well lighted and warm. It is also clean. Cows given good care actually produce more milk than do cows left outdoors or in cold barns.

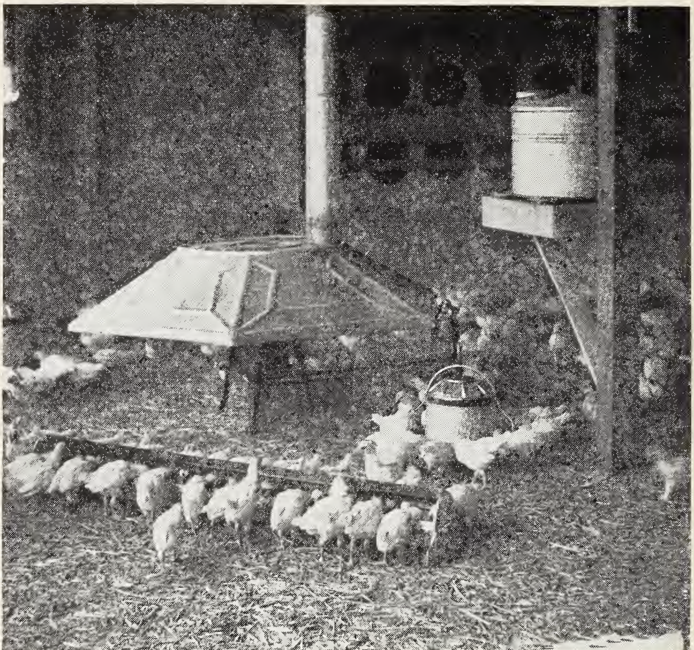
farmer controls the growth of crops chiefly by the things he does to the soil.

How is the soil prepared? There are about a dozen elements in the soil that plants require. Most of these elements are present in the soil in such large quantities that they will last for many years. But nitrogen, phosphorus, and potassium need to be replaced. Progressive farmers now fertilize the soil to put back those elements that their crops have withdrawn. Animals provide manure which adds nitrogen, phosphorus, and some potassium to the land. Legumes add nitrogen to the soil. But the only way to enrich the soil fully is to add commercial fertilizers.

Plowing the soil serves several purposes. It loosens the soil so that the roots of seedlings can grow easily. When the delicate roots first appear, they are not able to force their way through hard-packed soil. Cultivation also mixes air with the soil. The roots of plants must have air in order to grow. Heavy, clayey soils are especially in need of air.

Plowing in the fall has several advantages. More time is given for the decay of humus which has been turned under, thus increasing the supply of available minerals. It exposes the soil to the effects of frost, which helps to break it up into smaller particles. Fall plowing also helps to control certain insects that live in the soil, because they are exposed to birds and unfavorable weather conditions.

Experiments indicate that some soil is better not plowed, but cultivated by loosening it



H. D. Hudson Manufacturing Company

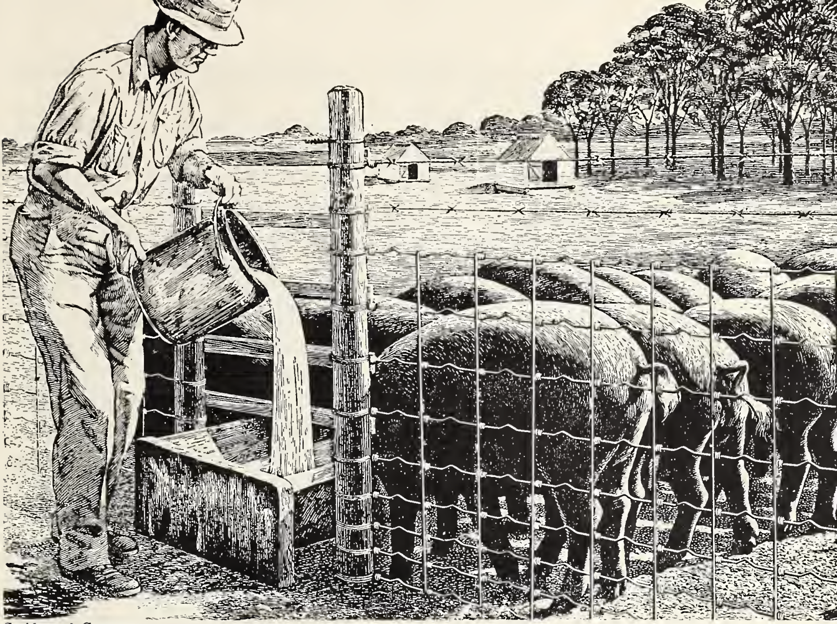
Young chickens require warmth, which is provided by the stove; food and water, which are kept before them in containers; exercise, which is provided by the litter; and the light to see by.

from the surface. This type of cultivation leaves dead vegetation on the surface and protects the soil from being blown or washed away. Soil cultivated by this method also holds water better than does a plowed field.

What is rotation of crops? Many farmers practice rotation of crops. This rotation may include three or four different crops which are planted in turn on successive years. A common three-year rotation is clover, wheat, and corn. In the southern states it may be clover, cotton, and corn. A four-or-five-year rotation may be used. The best rotation usually includes some legume, such as clover or alfalfa.

Experiments have shown that rotation of crops increases the yield. One experiment was carried on over a period of 30 years. One field was planted continuously to corn. The average yield was 34 bushels per acre. In another field a three-year rotation of corn, oats, and clover was practiced. In this field the average yield of corn was 50 bushels per acre.

Rotation of crops offers several advantages. It enriches soil by



Swift and Company

Animals, like people, need balanced diets. Hogs are healthier and grow faster when they have an adequate amount of protein in their diets. Skim milk provides this important food.

use of legumes. Rotation helps to control insects, for an insect that attacks one crop may not attack another and may be starved out in a field. Plant diseases are similarly controlled to some extent. The use of a cultivated crop in the rotation series makes possible the killing of weeds. If a field of wheat is badly infested with weeds, there is planted the next year some crop, such as corn, that can be cultivated. If a pasture crop is included in the rotation, the hoofs of animals pack the soil, and their manure enriches it.

Animals are less likely to catch diseases from soil that was not used for pasture the previous year.

And still another advantage of rotation of crops is that it enables the farmer to raise crops which will allow him to distribute his time economically through the growing season. One kind of crop may require special care at one time of the year, another crop at another time. For example, wheat and corn are planted at different times and they are harvested at different times. They make a good combination because they distribute the needed work during different months.

How are weeds controlled? It is important that crops should be

protected from weeds if they are to yield large returns. In one experiment the average yield in a properly cultivated cornfield was 40 bushels per acre. In a similar but uncultivated field it was less than a half a bushel per acre.

Chemicals can be used to control weeds. Some of them kill all plants on which they are sprayed. Others kill only certain types of plants, leaving others unharmed. One chemical has little effect on grasses, but will kill broad-leaved plants. This spray will kill weeds in grain fields, leaving the grain unharmed. Another method of controlling weeds is to burn them in the field with a flame thrower. A carefully controlled flame will burn weeds from between rows of corn without injuring the corn. Flame throwers are widely used to control weeds along railroads and highways.

Weeds can be controlled by cultivation in such crops as corn and potatoes that are grown in rows. This cultivation kills the weeds that have already started to grow and leaves a surface mulch that is so loose and dry that the conditions are unfavorable for the germination of weed seeds. Weeds rob the crops of light, water, and minerals.

In the pasture livestock cultivate weeds by eating the grasses. Lacking competition, the weeds produce seed and spread until they eventually ruin the pasture. Low useless shrubs, thistles, and other weeds replace the grass. The remedy may be to kill the weeds by use of chemicals, by use of a flame thrower, or by cutting them. It may be necessary to plow the pasture and re-seed it with useful grasses, allowing the grasses a year or two to become established.

To prevent introducing new weeds, some states require by law that anyone who sells certain farm seeds must have them tested for weed seeds. The bag must bear a tag giving the kinds and per cent of weed seeds present. Thus the farmer knows what he is buying. An effective control is to produce seeds only in fields freed of weeds by modern methods.

What care do animals need? The three most essential things needed in the care of animals are food, water, and shelter.

Animals need a balanced ration, just as people do. They need three kinds of nutrients: proteins, fats, and carbohydrates. Good sources of protein for cattle are alfalfa, soybeans, clover, and mill feeds, such as bran and cottonseed meal. Sources of fats and carbohydrates are corn, corn fodder, and barley. The best proportion for dairy cattle for milk production is about five or six pounds of fats and carbohydrates to one pound of protein.

All farm animals also need green food. This food is provided by pasture grasses. Turkeys and swine can get about 10 per cent of their food from green pasture.

Not only should the ration be balanced, but there should be a variety of foods. Cattle, like people, enjoy variety. The more food

a cow will eat and digest, the more milk she can give. An average dairy cow drinks about 15 gallons of water daily. This water should be warm. Dairymen often place heaters in the tanks during the winter to take the chill off the water. Water is essential for production of milk.

Grazing animals need a regular supply of salt. It may be sprinkled on their feed or kept in cubes in a yard or pasture. Cows give more milk if properly sheltered than if left outdoors in cold weather. The barns should be well ventilated and provided with plenty of light.

What care do chickens need? Nowhere is the effect of proper care better shown than with chickens. Because eggs are highest in price during the winter, this is the most profitable time for hens to lay.

Chickens should be given five types of food: dry mash, scratch feed, animal feed, green feed, and mineral feed. A dry mash may be made of corn meal, bran middlings, and ground oats. Scratch feeds include such grains as oats, wheat, or corn. In order to give the chickens the exercise they need to keep them healthy, grain is thrown among straw or litter where the chickens must scratch to get it. Animal feed is very important for egg production, since it is rich in protein. It is provided in meat scraps, skim milk, or buttermilk. During the winter, green food is provided by feeding mangels, sprouted oats, cabbage, and alfalfa leaves. Mineral feed is especially necessary for making the shell of the egg. It is provided in grit, oyster shells, and ground bone.

For high egg production it is especially important in the colder northern states that chickens should be provided with a warm, dry, sunny shelter during the winter. Today many chickens are grown in cages. Each hen has her own cage and is provided a constant supply of food and water. Artificial light keeps her awake and active.

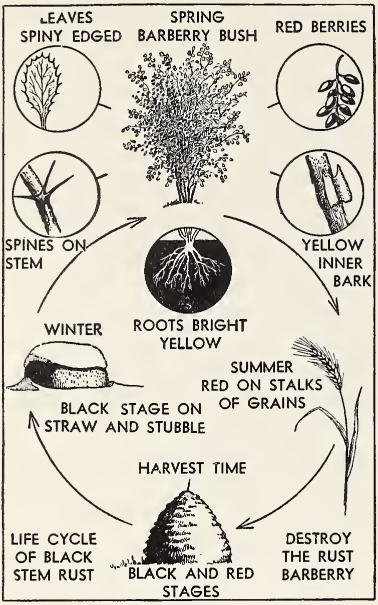
Exercise

Complete these sentences:

Growing different crops in succeeding years on the same area is called —1— of crops. The value of a legume crop is that it adds —2— salts to the soil. One advantage of plowing under turf is that it adds —3— to the soil. Weeds are a common cause of a —4— in yield of crops. One of the best ways to kill weeds is to —5— the soil. Rotation of crops helps to control —6— pests and plant —7—. Air is introduced into the soil by —8—. Green foods for winter may be fermented in a —9—. Alfalfa and clover are good sources of —10— for cattle. Chickens need —11— to make eggshells.

6. How do fungi affect our food supply?

Practically all the crops that man raises—whether fruits, vegetables, or grains—are attacked by various kinds of fungi. Almost



From this picture you can learn to identify the barberry which is a host of black stem rust, and you can learn how the rust passes through its stages of growth.

any part of the plant may be attacked—the leaves, the root, the stem, the seeds, or the fruit. Fungi are composed of masses of branching threads. These threads may gain entrance to the tissues of a plant in several ways. When a spore that has fallen on a leaf begins to germinate, the growing tip may pass through one of the stomates in the leaf and thus reach the active tissues. Spores may reach the interior of a plant through wounds. For example, when a branch of a tree is cut off and the surface is left exposed, the spores can enter. From these spores there may develop threads which enter the living tissues of the tree and send out little suckers which pierce the cell walls and absorb the nourishment from the cells. Besides injuring the plant by robbing it of its food, it may also secrete poisons which have a harmful effect on the plant.

How are plant diseases spread? The fungi that cause plant diseases reproduce by means of microscopic spores. They are produced in enormous numbers and are spread by the wind, by insects, by animals, by rain, and by running water. People themselves are important agents in spreading these diseases. Seeds, bulbs, and tubers which are already infected may be carried for long distances. Spores may be carried by the different means of transportation—automobiles, trains, and even airplanes. New plants that are brought into the country from foreign countries may be diseased.

What are some common plant diseases? Plants which are attacked by diseases show certain signs by which we may know that they are diseased even though we cannot see the fungi that cause the disease. The symptoms that plants exhibit make it possible to classify plant diseases into certain types.

Examples of plant diseases are blights, wilts, smuts, mildews, rusts, and rot. Blights most commonly attack leaves and cause them to dry up very suddenly. Wilts are diseases which cause the plant suddenly to wilt and

International Harvester Company

This modern sprayer blows a misty cloud of chemical spray over a citrus orchard. Both insect pests and plant diseases may be controlled by use of spray.

droop. The chief symptom of smuts is the production of black dusty spores, usually in the seed head. Rusts are recognized by the rusty-red or orange color of the masses of spores which occur on the leaves, stems, or fruit of many plants.

The black stem rust found on grains is the most destructive of all the plant diseases. The chief harm is done to wheat, but it also attacks oats, barley, and rye. The fungus that causes this disease must have two hosts to live on in order to complete its full life history. These two hosts are the common barberry and wheat or some other grain. It lives first on one and then on the other. During this complicated history it passes through three stages and forms three kinds of spores: the red, or summer stage; the black, or winter stage; and the yellow, or spring stage. The red and black stages are found on the wheat and the yellow stage on the leaves of common barberry.

In the spring the spores are blown from the barberry to the wheat where it lives on the stem and leaves and grows rapidly, producing red spores, which are blown about and may infect other plants. A new crop of spores may be formed every 10 days. This is called the repeating stage. These summer spores cannot live over the winter in regions north of Texas. In the autumn there appears the black

stage, which passes the winter on the stubble and old straw. In the spring, spores are carried to the barberry, where clusters of yellowish spores are formed. These spores are blown to the wheat and thus the cycle goes on.

The best way to control this rust is to destroy the barberry. Bushes may be dug up or they may be killed by applying salt or kerosene to their roots. However, it is necessary to distinguish between the common barberry, which is harmful, and the Japanese barberry, which is entirely harmless and is widely used for ornamentation of home grounds.

How may plant diseases be controlled? Certain factors naturally help to restrict the spread of diseases. A certain disease is generally confined to one plant or to a group of closely related plants. Since the stem rust which attacks wheat does not attack apples or potatoes, the spores that fall on plants other than wheat do no harm. Many fungi can live only on some certain part of the plant. The brown rot of peaches is found only on the fruit and seldom does any harm to the leaves or stem. Sometimes the period during which the fungus can harm a plant is limited to a certain stage in the plant's development. The stinking smut of wheat must attack the young shoots within a few days after germination in order to do any harm. Since some fungi require two hosts, if either host is destroyed the fungus cannot continue its development.

Certain farm practices help to control plant diseases. One of these is rotation of crops. A plant disease is usually limited to one crop, and if the kind of crop that is grown in a field is changed, the spores of the disease that attacked the last crop will not usually attack a new plant. The destruction of weeds also helps to solve the problem, for plant diseases may first live on weeds and then transfer themselves to neighboring crops. It is well to burn diseased leaves and stalks in the autumn or to plow them under.

Chemicals may be used in several ways in controlling plant diseases. When larger branches of trees are cut off, spores of the fungus rot may be prevented from entering the wound by applying a thick coat of paint. When seeds are covered with spores, the spores may be killed by treating the seeds with such chemicals as copper sulfate or formaldehyde. Wheat seeds are treated in this way for smut and seed potatoes for potato scab.

Chemicals may be applied to the plants in the form of a spray or dust. When the threads of the fungus grow on the surface of the leaves or fruit, as mildew does, they may be killed by the application of the proper chemical. Usually, however, the threads are inside the tissues of the plant where they cannot be reached by chemicals. Chemicals are used to kill the spores of these fungi.

During the fall or winter, while fruit trees are dormant, chemicals are applied in suffi-

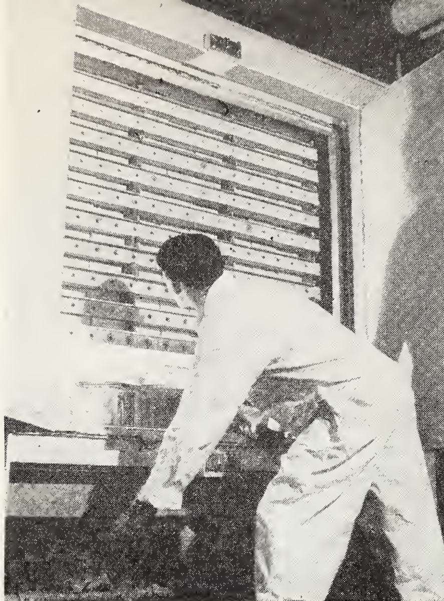
cient strength to kill the spores that may be wintering there. Other sprays are applied during the growing season, covering the plant with a thin coating of chemical which will kill the spores that may later be brought to the plant.

Do fungi affect stored foods? Three groups of fungus plants, bacteria, yeasts, and molds, particularly attack stored foods. They all give off enzymes which change the foods to forms which they can use. Bacteria cause decay, yeasts cause fermentation, and molds decay and spoiling.

Some action of these fungi is desirable. Cheese obtains its flavor from the action of molds. Bacteria sour milk and give flavor to butter and cheese. Yeasts are used to produce carbon dioxide in white bread, and make it light and porous. Yeasts also produce several kinds of alcohol. Some yeasts are useful for food.

Foods can be prevented from spoiling in several ways. Stored grains, legumes, and hay need only be kept completely dry, for fungi cannot grow without water. Many kinds of foods are dried to preserve them—milk, vegetables, soup mixes, fruits, sugars, and fish. Since fungi need warmth for growth, many foods are protected by storing them at low temperatures. Some foods will keep well at temperatures just above zero.

Foods can also be preserved by canning. In canning it is necessary to kill all spores and living organisms by heating the food,



Birds Eye Frosted Foods

This man is loading a modern quick-freezer with packages of chicken prepared for cooking.

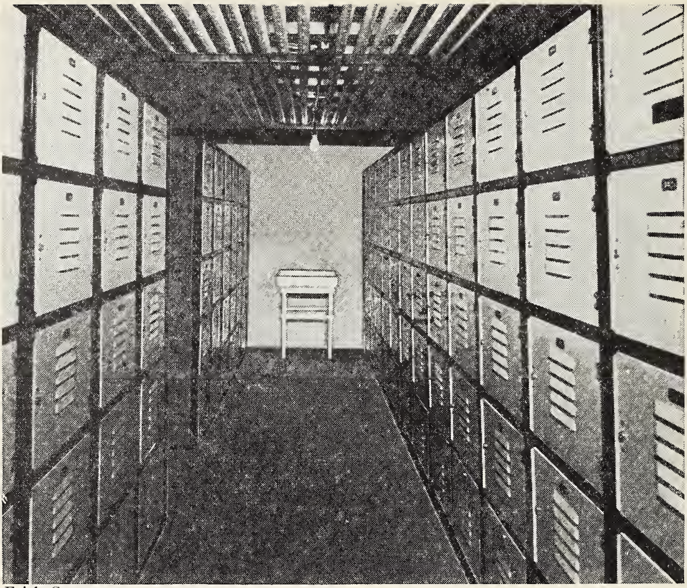
and then to seal it so that air cannot enter. Unless canned protein foods are thoroughly cooked, bacteria may remain in them and produce deadly poisons.

Other methods of preserving food including pastuerization, pickling, and use of chemicals.

Exercise

Complete these sentences:

Most fungi which cause plant diseases reproduce by means of —1—. Fungi absorb —2— from cells of the host plant, and give off —3— which damage it. Smuts and rusts are most damaging to —4— crops. The spring stage of the black stem rust lives on the —5— plant. Changing of crops by —6— deprives some diseases of hosts. En-



Frick Company

Food-storage lockers are not spectacular in appearance, but their use may revolutionize the eating habits of people in many areas. Frozen fresh fruits and vegetables provide needed foods.

zymes given off by fungi help them to —7— food. Stored foods may be protected from spoiling by keeping them —8—, by storing them at low —9—, and by sealing them away from —10—.

7. What animals destroy our food supplies?

Although many kinds of animals may destroy valuable crops, three great groups, the insects, the worms, and the rodents, are far more harmful than the rest.

Why are insects pests? Insects are by far our worst enemies among animals. They reproduce so rapidly and they are so difficult to find that any permanent reduction in their numbers is out of the question.

As civilization has advanced in this country, insects have become a more serious threat because of man's activities. When the forests were cleared and more acres were planted to wheat and other crops, a larger food supply was provided for those insects that fed on such crops. And when new crops were introduced, new insects appeared with them. Formerly the potato beetle was found only in Colorado, feeding on wild plants related to the po-

U. S. Bureau of Entomology and Plant Quarantine

The potato plants in the foreground were not sprayed and, as a result, were nearly destroyed by Colorado potato bettles. The plants in the background were sprayed.

tato. When potatoes were raised there, these beetles began to feed on the potato plants and soon spread to all parts of the country where potatoes were grown.

Also, we have unintentionally brought into this country serious insect pests from abroad. Some of the worst pests we now have were thus introduced from Asia and Europe, among these are the cabbage worm, the Japanese beetle, and the European corn borer.

We and the insects want the same crops for food. If we did nothing to control potato beetles, undoubtedly they would eat nearly all the potato crops. Grasshoppers sometimes destroy most plants over large areas. Many kinds of insects at times may become so numerous as to become serious pests.

The two kinds of insects are those with chewing mouths and those with sucking mouths. Common examples of chewing insects are grasshoppers and army worms. Army worms, which are a kind of caterpillar, at times appear in countless numbers, and in a short time may destroy a whole field of grain and then pass on to do equal damage to neighboring fields.

Equally destructive are the sucking insects. The presence of chewing insects is indicated by

U. S. Bureau of Entomology and Plant Quarantine

The apple worm is not a worm. It is the larva of the codling moth. Spraying apple blossoms just as the fruit begins to form kills a large proportion of codling-moth larvae.

holes eaten in the leaves or by the disappearance of the leaves. The presence of sucking insects is shown by the curling of the leaves or the wilting of the whole plant. Among the most common of the sucking insects are the plant lice, or aphids, of which there are many kinds that may attack a great variety of plants. One of the most destructive is the pea aphid. A machine devised for the purpose collected 11 pounds of these aphids from 2½ acres of peas. Since it takes about a half of a million aphids to weigh a pound, there were about 2,000,000 aphids to each acre of peas.

Some insects feed within the tissues of plants, where they may not be seen. Some of them are called borers. One of the most common borers is the corn-ear worm, which feeds on the kernels of corn just under the husk at the tip of the ear. Internal feeders, such as the melon worm and the bean weevil, found in fruit and seeds are often called worms or weevils. Some insects spend only one life stage inside the fruit or seed. Other insects spend all their life stages there.

Still other insects live in the ground and feed upon the roots or other underground parts of plants. The white grub [the larva of the June beetle] does damage to potato tubers and to the roots of strawberries. They are apt to be present in newly turned sod.

Insects may injure growing crops indirectly by acting as carriers of plant diseases. The holes left by the feeding insects give an opportunity for the spores in the air to enter the plant. In some cases it is known that the insects introduce the spores directly into the plant on their mouth parts. Elm diseases are carried by leaf hoppers and by a beetle which lives in tunnels beneath the bark.

Products stored for use, are not safe from the attacks of insects. Various kinds of foods, especially those derived from the seeds of cereal crops, are injured by insects. The insects that eat stored food are found chiefly among two groups: beetles and moths. The beetles are injurious in both the larva and adult stages, the moths only in the caterpillar stage. You may have seen larvae of beetles in "wormy" flour or corn meal.

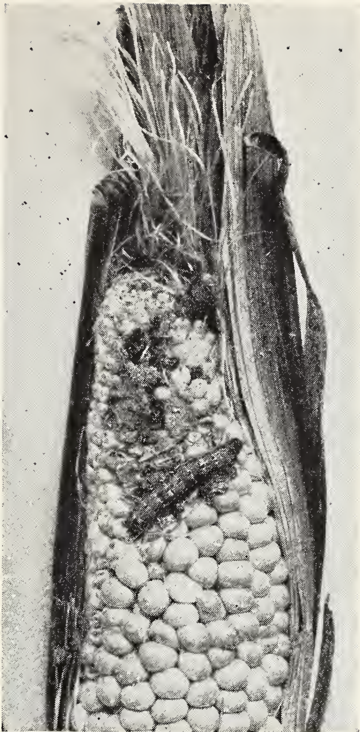
Some insects may even attack wood. Among these is the termite. This insect may destroy books or furniture or may undermine foundations of buildings. It works away from the light inside the part attacked and may do great damage before its presence is known.

A common pest in the house is the clothes moth which, in the caterpillar stage, feeds on fur and woolen goods. It uses some of the fibers in constructing its cocoon.

Insects attack domesticated animals in a variety of ways. Sometimes they may merely annoy the animals in such a way as to cause a stampeding of horses and cattle.

More serious are those insects that live as parasites on animals. Some of these parasites are external, living on the outside of the animals and sucking blood.

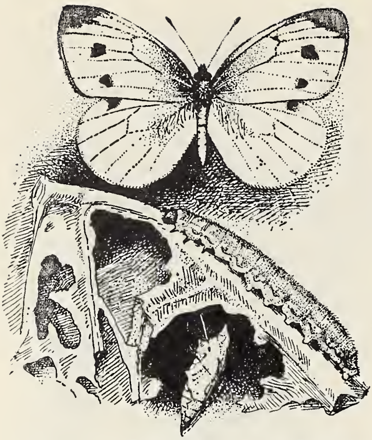
Some eat dry skin and parts of the feathers, as does the common poultry louse. Other insects are internal pests, living inside the bodies of animals and causing great discomfort and injury. For example, the ox warble lives just under the cow's skin. It damages the hide, thus rendering it less valuable for making leather. Horse bots live in the alimentary canal of the horse, causing a rundown condition.



U. S. Bureau of Entomology and Plant Quarantine

The corn earworm damages much of our table corn supply by eating kernels from the tip of the ear.

What harm do worms do? The most harmful of the worms are small, ranging from 1/64 to 1/25 of an inch long, and are called nematodes. They have common names such as wireworms, eelworms, and roundworms. They generally live in



U. S. Bureau of Entomology and Plant Quarantine

The cabbage worm feeds on leaves of the cabbage. Above is the cabbage butterfly. The pupa is suspended from the leaf.

the soil. One kind, which attacks 1500 varieties of plants, causes knots on roots. Other kinds attack the roots of citrus fruits, potatoes, rice, sugar beets, and shrubs. A meadow nematode eats roots of grasses, corn, peanuts, and tobacco. These worms are so deadly to plants that certain plants cannot be grown at all where they are most abundant. When these worms were destroyed in one lettuce field, yield was increased eight times. Pineapple yield increased three times when the worms were killed.

What damage do rodents do? The rodents are the gnawing animals—rats, mice, rabbits, ground squirrels, gophers, and beavers. Every one of these is a destructive animal. Fleas carried by rodents spread disease. Rats are the worst pests of all rodents, for they not only eat field crops, but eat stored foods, kill chickens, gnaw into houses where they do damage and carry filth and disease. Field mice are particularly destructive to grain in the field. Rabbits and ground squirrels eat growing crops, and rabbits gnaw bark from valuable trees. Gophers burrow in lawns, gardens, and meadows, where they eat roots and vegetables. Beavers destroy standing timber and fruit trees, but also do much good in regulating floodwaters. Beavers should be protected, but should be moved to areas where there are plenty of trees.

Exercise

Complete these sentences:

The cabbage worm is the —1— of a butterfly. Our worst enemies among animals are —2—. Aphids are insects with —3— mouth parts. Grasshoppers have —4— mouth parts. The white grub is the larva of the —5—. Beetles may be injurious in both the —6— and the —7— stages. Moths are injurious only in the —8— stage. Nematodes attack the —9— of plants. Some insects carry plant —10—. The poultry louse is an example of an external —11—. The most destructive rodent is the —12—.

8. How can we control harmful animals?

Even though the animals which destroy our food and fiber supplies belong to different groups, similar methods of con-

E. I. du Pont de Nemours and Company

Spraying these cattle with an insecticide, methoxychlor, protects them from insect-carried diseases and increases their yield.

trol may be used for all pests. Different ways of applying them must be worked out for different animals.

How are poisons used to control pests? All poisons are chemicals. Poisons are used to kill insects by spraying, by dusting, and by putting out poisoned bait. Insects which chew the plant may be poisoned by spraying poison onto the plant. This type of poison, called a stomach poison, need not be put directly on the insect. An insect which sucks plant juices cannot be poisoned by poisoning its food supply. The best method of killing these insects is to apply the spray directly to the insect, but this requires careful spraying at the right time. A third type of poison, of which DDT is the best known, is sprayed on plants, and it kills the insect when its body or feet come into contact with the poison. DDT will remain effective for several days on plants and for several weeks on walls inside buildings.

There is no poison which kills all insects and plant pests. For example, when DDT is used on a garden or orchard, most aphids and many small ticklike animals called mites escape death. The natural enemies of these pests, the ladybird beetle and lacewing fly, are killed by the DDT. Honeybees which pollinate flowers may also be killed by sprays.

Several common poisons are used in sprays. Nicotine sulfate or black leaf 40 is effective against aphids. Arsenate of lead kills insects with biting mouths. Paris green is mixed with baits for insects.

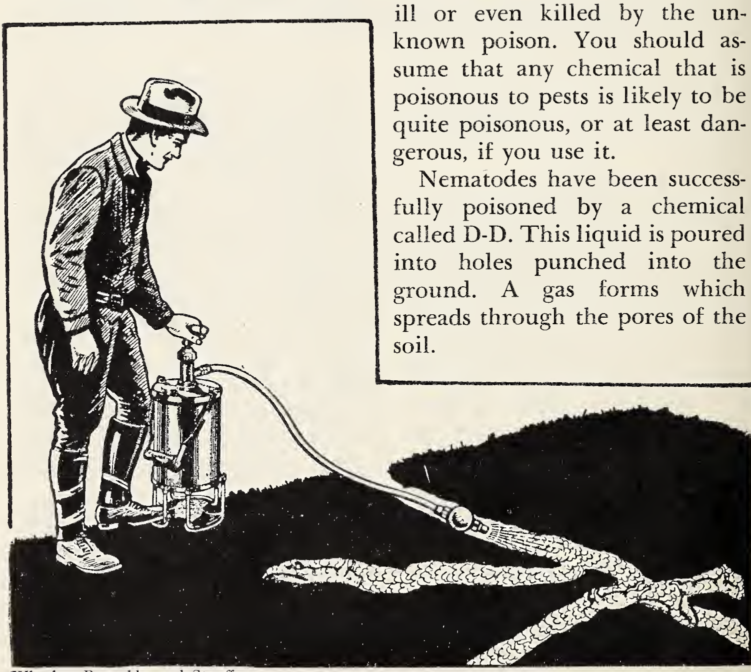
Until recently, sheep and hogs were dipped into chemicals by

causing them to swim through a tank to kill ticks and insects on their bodies. Now spraying with high-pressure sprayers is accomplishing the same purpose. Almost no wood ticks cling to sheep, dogs, or other animals sprayed completely with a water solution of DDT or an equally effective chemical.

To control flies, cockroaches, bedbugs, and mosquitoes houses may be sprayed with a kerosene solution of DDT. Lamp cords, screens, and other areas where insects are found should be sprayed two or three times yearly. Any such spray is poisonous to some extent. In order to be safe cover your mouth and nose with a moist cloth when using any poison spray. DDT powder may be used on dogs to kill fleas, but not on cats because they lick themselves. Another chemical, chlordene or 1068, is particularly deadly to cockroaches and grasshoppers and is effective against many other insects.

Very frequently a new poison is introduced on the market without sufficient study of its dangers to human beings. Only after years of use are the real effects fully known. In the meantime, many people may be made ill or even killed by the unknown poison. You should assume that any chemical that is poisonous to pests is likely to be quite poisonous, or at least dangerous, if you use it.

Nematodes have been successfully poisoned by a chemical called D-D. This liquid is poured into holes punched into the ground. A gas forms which spreads through the pores of the soil.



Wheeler, Reynolds, and Stauffer

An effective method of killing burrowing rodents is to blow a poisonous gas into the burrows, and then to seal the burrows. The animals are ground squirrels.

Rodents are poisoned by use of poison bait, by poison gas introduced into their burrows or hiding places, and by a contact poison which they pick up on their feet. When they lick their feet they are poisoned. It is not unusual to kill from 100 to 400 rats around a barn in one effective poisoning campaign. There are poisons which are deadly to mice and rats, and not particularly dangerous to other animals. They are the safest to use. Carbon monoxide from an automobile exhaust may be used to kill burrowing rodents.

What are mechanical methods of control? Mechanical methods of control can best be explained by giving specific examples. One such method is to screen windows and doors to keep out flies and mosquitoes. When young tomato plants are first set out, they may be protected from cutworms by wrapping a piece of heavy paper around the stems. The cucumber beetle is a common insect, destructive not only to cucumbers but to such other vine crops as melons, squash, and pumpkins. Most of the harm is done to the young plants. These plants may be protected by placing over each hill a square wooden frame covered with cheesecloth. The egg masses of the tussock moth may be collected during the winter and burned. Sticky bands placed around tree trunks will prevent insects from crawling up the tree.

Electrically charged screens kill insects, but are harmless to people.

U. S. Bureau of Entomology and Plant Quarantine

This tiny wasp is laying its eggs in the body of an aphid. The egg will hatch out a tiny parasite which will devour the aphid as it grows.

Keeping rats away from food, and food away from rats, is the best method of controlling this pest. Building houses and barns on solid concrete foundations will prevent rats from entering buildings. Houses properly set off the ground on concrete foundations will prevent termites from entering. Since termites will not crawl out into the light, they build tunnels along concrete foundations until they reach a point where wood is in contact with moist soil. Most wooden buildings in this country are vulnerable to attack by termites. The food of termites is the wood which is eaten away as they make their tunnel homes. About the only way to protect buildings against termites is to avoid all contact of wood with soil, and to inspect walls to locate tunnels if the pest appears.

Trapping is a mechanical method of control used frequently to catch mice, rats, rabbits, and ground squirrels. There are many types of traps available.

What are some agricultural methods of control? Agricultural methods include perform-

ance of farm operations in such a way as to destroy insects or prevent them from injuring crops. As you know, both fall plowing and rotation of crops are of value in controlling insects. The time of planting may also be a factor in insect control. For example, wheat planted late is not as seriously affected by the Hessian fly as is wheat planted early.

What are some biological methods of control? The most satisfactory method of controlling insects is to permit other living things to keep them in check. Birds eat many insects. Another important factor in keeping insects in check is other insects. Insects may live as parasites on other insects. The eggs of the parasite are laid on the host insect, and as the young hatch they eat the tissue of the host. At first the host is not completely destroyed, but eventually the parasite kills it as the young parasite completes its growth. Some of these parasite insects are almost microscopic. Some are so tiny that they pass their entire life history inside an insect's egg.

Predators are animals which eat other animals. Dragonflies, lady beetles, and ground beetles are insect predators which eat other insects. The young ladybird beetles, as well as the adults, destroy aphids. The table on this page shows the chief differences between predators and parasites.

One of the unfortunate effects of spraying is that predators as well as pests are killed.

Biological control of rodents depends chiefly upon protection of hawks, owls, foxes, snakes, and other animals often considered to be pests. Use of cats to control rodents is not generally effective, for the average cat will not kill them. Kittens generally do not kill mice unless they are trained to do so by an older cat. Dogs, particularly the terriers, may be trained to kill rats.

Exercise

Make a table by ruling your paper into four columns. Head the columns as follows: CHEMICAL METHODS, MECHANICAL METHODS, AGRICULTURAL METHODS, BIOLOGICAL METHODS. *In the correct column write the following phrases or words*: rotation of crops, encouraging birds, screens, stomach poison, fall plowing, wrapping stems with paper, importing beetles, contact poison, poison bait, sticky bands on tree trunks, late sowing of wheat, concrete foundations, traps, protecting snakes.

PARASITES	PREDATORS
Eggs laid on host	Eggs laid in various places
Host is usually larger	Prey is usually smaller
Feed on one kind of insect	Prey on many kinds of insects
Destroy only one individual	Destroy many individuals
Kill host slowly	Kill prey quickly

9. Why should most birds be protected?

The practical value of birds depends on their food habits. When they feed upon things that are harmful, such as injurious insects and weed seeds, birds are useful. When they feed on things that are valuable, such as fruit and grain, birds are harmful. Careful studies of the food habits of birds have shown that the good that birds do in destroying harmful pests is many times greater than the slight harm they do in eating valuable products. No other group of common animals has so few harmful members.

How has the food of birds been determined? For many years the Bureau of Biological Survey has been making a scientific study of the food of birds. Experts examine the contents of the stomachs of hundreds of birds and thus are able to determine on what the bird has been feeding.

For example, in studying the food habits of the robin, more than 1200 specimens were collected from 42 states. The food was found to be about equally divided between animal and vegetable matter. About one-third of its food is composed of harmful insects, about one-seventh of materials valuable to man [fruit and beneficial insects], and about one-half is composed of wild fruit, which is of little significance to man.

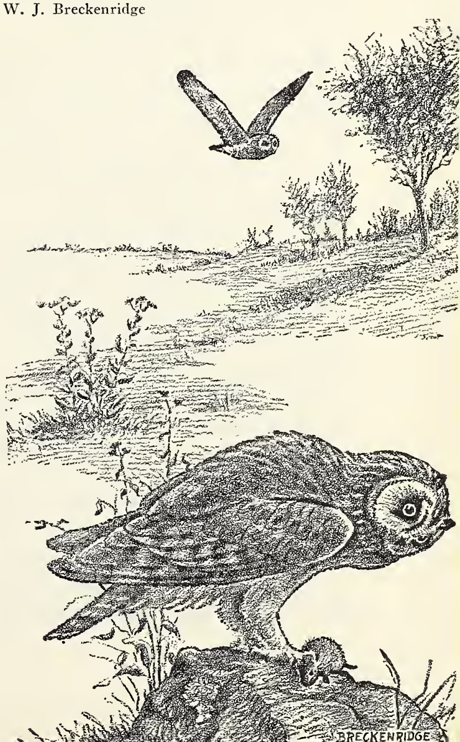
The food habits of practically all our common birds have been studied. By referring to the reports of these studies, the economic standing of any bird can be ascertained.

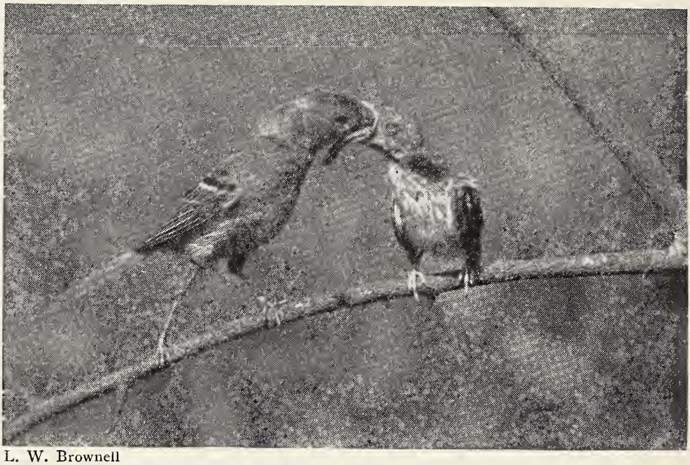
These studies have shown that birds are of practical value in three ways. They eat harmful insects. They eat weed seeds. They eat rodents.

How do birds help control insects? Insects constitute the chief food of our songbirds, and for many birds, insects make up practically their entire diet. Upland game birds, such as quail and pheasants, eat many insects.

The short-eared owl is a mouse-eater. The average stomach examined contained one or two mice.

W. J. Breckenridge





L. W. Brownell

While the diet of sparrows generally consists of seeds, the young are fed on caterpillars and other forms of insect life. This is a field sparrow mother and young.

Although some of the insects eaten are beneficial, the great majority are harmful to man.

Birds are so active, and the temperature of their blood is so high [from 102 to 112 degrees Fahrenheit] that they require large numbers of insects to supply sufficient energy for life.

Most birds feed on many different kinds of insects. The cuckoo is known to feed on at least 65 kinds of insects, the robin on 229 kinds, and the nighthawk on 600 kinds.

Many of our common insect pests are eaten by a great variety of birds. The potato beetle is eaten by at least 26 kinds of birds, the white grub by 57 kinds, and the cutworm by 88 kinds.

Almost everywhere that insects are found, birds are present to feed upon them. Swallows capture insects in the air, woodpeckers drill holes in the trunks of trees and spear insects hidden there. Native sparrows feed on insects found in the ground. Some shore birds devour mosquito wigglers. Many birds collect insects from the leaves of trees.

Do birds eat weed seeds? Many birds are beneficial because they feed on weed seeds. However, not so many birds feed on seeds as on insects. No bird feeds entirely on weed seeds. The two champion weed-seed eaters are the mourning dove and the horned lark. Weed seeds form nearly two-thirds of the food of these birds. Other birds that feed on weed seeds are the native sparrows. Weed seeds make up about half of their food.

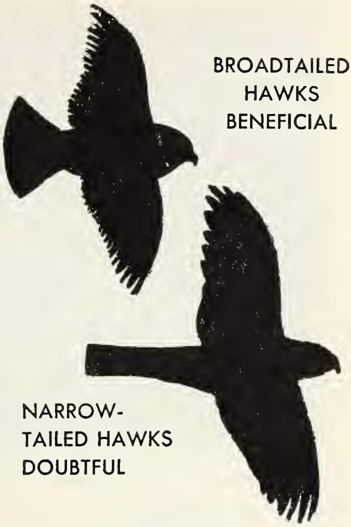
Seven hundred seeds of pigeon grass have been found in the

stomach of a tree sparrow, and 10,000 seeds of pigweed in the stomach of a bobwhite. It has been estimated that tree sparrows in the state of Iowa eat 875 tons of weed seeds every year.

What birds eat rodents? Hawks and owls are valuable because they eat mice and other rodents. Probably no group of birds is so much misunderstood as these birds. It is a quite common but mistaken notion that they are harmful. Some hunters believe that they are performing a good service when they shoot a hawk or an owl.

From the standpoint of their relation to man, U. S. Bureau of Biological Survey studies show that hawks and owls may be divided into three groups: beneficial, harmful, and neutral—that is, birds in which the harmful and beneficial qualities nearly balance.

The bulletin summarizing the results of the studies made of the food habits of the hawks and owls states: "The result proves that a class of birds, commonly looked upon as enemies to the farmer, and indiscriminately destroyed whenever occasion offers, really rank among his best friends, and with few exceptions should be preserved and encouraged to take up their abode in the neighborhood of his home. Only 6 of the 73 species and subspecies of hawks and owls of the United States are injurious. Of these, three are so extremely rare that they need hardly be considered, and another [the fish hawk] is only indirectly injurious, leaving but two [the sharp-shinned and Cooper's hawks] that really need to be taken into account as enemies to agriculture."



By studying hawks in flight, you can identify the two general types. Can you name several species of each type and tell what they eat?

A former chief of the Bureau of Biological Survey estimated that each hawk and owl is worth $20 a year to the farmers on account of the rodents it destroys.

Are there any harmful birds? Although birds as a class are beneficial, a few birds in some ways do a little harm. Probably the chief harm done is in the destruction of fruit and grain. However, most of those birds still do more good than harm. But there are a few birds which, taking all things into account, must be considered harmful and not worthy

There are many species of quail. These of California, like others, are beneficial birds both in their eating habits and in their ability to provide sport and meat.

of protection. The English sparrow is one because it drives away martins and bluebirds and eats grain; it does little useful work. The European starling is a pest for much the same reason as is the English sparrow. The sapsucker is a woodpecker which injures trees. The sharp-shinned hawk feeds on valuable birds, and Cooper's hawk feeds largely on poultry. Perhaps others are definitely harmful under differing circumstances.

Are there fifty-fifty birds? There are several birds whose good and bad qualities about balance. The crow and the crow blackbird, or grackle, are examples of such birds. They are

FOOD CHART OF TEN BIRDS

Name of bird	Good done		Harm done			
	weed seeds (per cent)	insect pests (per cent)	grain (per cent)	tame fruit (per cent)	good insects (per cent)	general standing
Downy woodpecker	....	69	....	....	2	Beneficial
English sparrow	24	....	74	....	....	Harmful
Flicker	....	55	1	....	2	Beneficial
Grackle	4	19	22	3	6	Doubtful
House wren	....	69	....	....	6	Beneficial
Kingbird	....	50	....	....	13	Beneficial
Meadow lark	7	56	3	....	12	Beneficial
Mourning dove	64	....	8	....	....	Beneficial
Robin	....	33	....	8	6	Beneficial
Song sparrow	50	18	2	....	2	Beneficial

harmful because they eat grain and other birds' eggs, but do good by eating insect pests and weed seeds.

Is bird study a source of pleasure? Many more people enjoy birds of all kinds than hunt game birds. The pleasure in studying birds comes from identifying them, watching them for habits peculiar to each kind, recognizing them by their songs, and observing how they build nests and feed their young. People also derive much pleasure from making nesting boxes, feeding the winter birds, and providing fountains.

Exercise

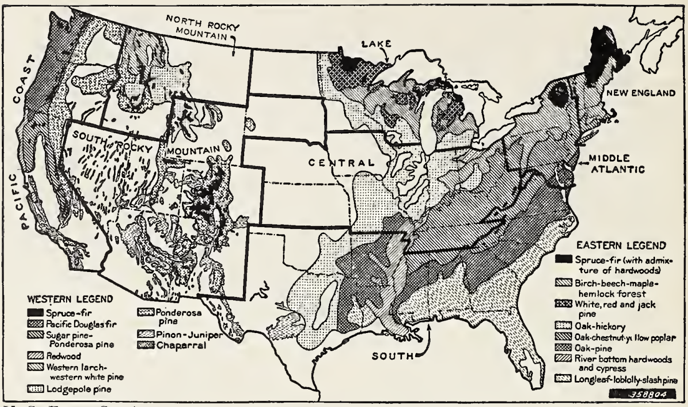
Complete these sentences:

The quail is valuable in destroying weed seeds and —1—. —2— birds are a source of pleasure to millions of hunters. The worst bird all over the United States is the —3—. Most —4— and —5— are useful because they feed on rodents. —6— make up most of the food of songbirds. Our native sparrows feed on both weed seeds and —7—. The most useful enemy of insects is —8—. A harmful woodpecker is the —9—. The most destructive hawk in destroying poultry is —10— hawk.

10. How can we conserve natural resources?

The conservation of forests, grasslands, water supply, wild game and fish, and soil is so important that our survival as a nation may well depend upon it. Our immediate problem is to start with what remains of a once rich supply, and to try to rebuild it to protect our national safety. This is not easy, for ignorant and greedy individuals are constantly trying to destroy our remaining natural resources. Some lumbermen still want to cut forests without replacing them. Some cattlemen and sheep growers want to pasture remaining grasslands until the grass is destroyed. Hunters want to kill the last of the game birds and animals. Farmers are still cutting forests and plowing grasslands which are not fitted for agriculture. Our forests and water supply are threatened by people who set fires because of carelessness, viciousness or a desire to see things burn. The only remedy seems to be to regulate by state and federal law the use of natural resources for the common good. The conservation program must be in the hands of trained scientists to be effective.

How can forests be conserved? There are not enough forests left today to supply our needs for lumber, poles, paper, railroad ties, and other wood products. We can conserve our forests by using to best effect those we have. This involves harvesting only such trees as are mature. A tree reaches a point after which it grows only slightly, and becomes increasingly likely to die from disease or decay. Mature trees should be harvested without dam-



U. S. Forest Service

This map shows to some degree how complex the mixture of forest trees really is. Study it in detail, particularly in your locality.

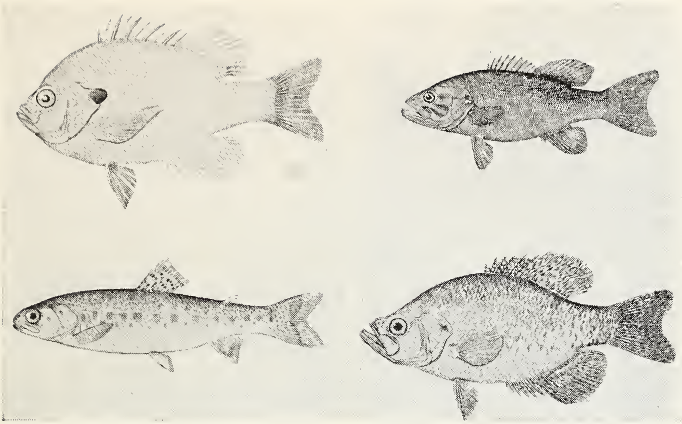
age to other trees. When mature trees are removed on a large scale, enough should be left to protect the soil on steep slopes and to provide seed for new forests.

Protection of our forests from fire is necessary. Greatly improved methods of fire fighting are being worked out, involving use of fire watchers working from towers and airplanes, dropping fire fighters from planes to put out fires when they are still small, improved pumps, and other equipment for use of fire fighters. Prevention of fires is still more necessary. More than one-fourth of all fires are set deliberately by people who are either ignorant or not quite normal in some way. Careless smokers set another one-fourth of forests fires. Burning debris and brush, lightning, careless campers, railroads, and other minor causes start the rest of the fires. There are large areas of forest land on which nobody should live at all. There are other areas where campers and others should be restricted to protected areas.

Another way of preventing spread of fire is by proper use of forests. If all branches and other brush from lumbering are piled in open spaces and burned in wet weather, fire is less likely to spread. Open strips, called fire trails, prevent the rapid spread of fire.

Substitution of other materials for forest products saves our forests. Concrete, stone, and brick may be used for building. Use of sugarcane pulp wallboards saves lumber. But just as important is the complete use of all forest materials. Sawdust and shavings may be made into pressed boards, or pressed into bricks for fuel. Waste paper may be reused. A yeast useful for livestock food can be grown on wood waste.

Reforestation, which is the



U. S. Fish and Wildlife Service

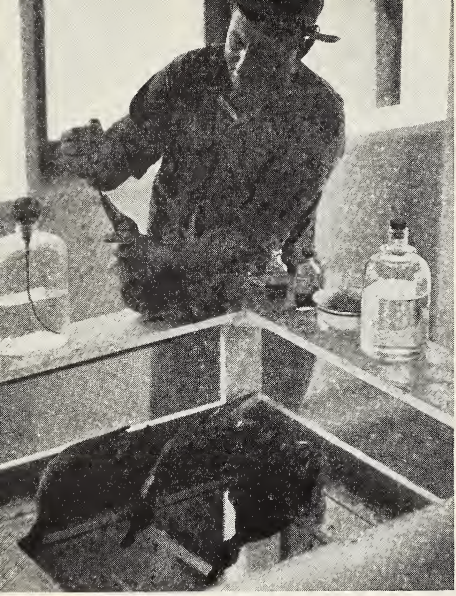
Many people cannot recognize the common game and pan fish. Perhaps a study of these will help you know these fish when you see them. At the top, are the sunfish (*left*) and the small-mouthed black bass. At the bottom are the brook trout (*left*) and the crappie.

planting of trees and encouraging growth of trees by natural means, is slow and expensive, but much of our forest land is so badly damaged that no other remedy will work. It is particularly difficult to conserve forests because only about one-third of forests are publicly owned by the United States and the various states. It would be highly desirable for cities and counties to buy forest lands in their neighborhoods, and to sell the timber for revenue. Publicly owned forests are almost always better operated than are privately owned forests. A few owners of large forests have effective programs for renewing, protecting, and harvesting forests scientifically. These owners generally operate where few people live.

Much forest land is in small areas on farms. The farm woodlots of a community, if properly managed, will supply trees to operate a small sawmill indefinitely. Woodlots may serve as windbreaks, protect sloping ground from erosion, provide fence posts, and control drifting snow.

Why should we save wild animals? Wild animals have several direct values. Furs of rabbits, muskrats, beavers, and other animals are useful. Some animals, particularly deer, thin the forests by keeping plant growth in balance. Other animals, by eating game animals, maintain a natural balance in the forests. Another real value of animals is the pleasure people derive from seeing them.

There are not many large wild



U. S. Bureau of Biological Survey

Ducks get sick from a number of causes. This duck is in the hands of a doctor receiving treatment—apparently not on an entirely voluntary basis. This work is carried on by the Bureau of Biological Survey of the United States Department of Agriculture.

animals left. Deer are most plentiful, and occasionally become too numerous for their food supply. There are about 165,000 antelope and not quite so many bears in this country. There are a few thousand elk and bighorn sheep, a few hundred moose, and a few buffalo. In all there are probably not more than seven million large game animals left, or about one for each 23 people.

A few animals, such as foxes, wolves, ground squirrels, rabbits, woodchucks, weasels, red squirrels, and wildcats are pests and can generally be hunted with beneficial results. But for the rest hunting must be carefully regulated to take only the number that would die for lack of food if left alone. This is a problem for experts to solve. We must recognize that hunting is a sport no longer available to most people.

Can we conserve game birds and fish? Some of the game birds are now extinct. Passenger pigeons and heath hens are among them. Almost extinct are several kinds of ducks, the woodcock, and the native prairie chicken.

Fish will maintain themselves if lakes and streams are kept clean, if shorelines are covered with vegetation, and if they are protected during spawning season. Lakes and streams may occasionally be closed to fishing to permit small fish to gain sufficient size to make them valuable.

The most important protection wildlife needs is a safe place to live and one which will provide enough food. Waterfowl need protected swamps and lakes. Gamebirds require brush and weed cover. Songbirds require trees or shrubs. Most wild animals need forest or grasslands to furnish food and protection.

Clearing land for farming has been the greatest single cause of the decline in wildlife. Grazing cattle remove vegetation from shorelines of ponds. Soil from unprotected lands washes into streams and kills the fish. Industrial wastes and sewage pollute streams. Draining swamps to provide farmland or for mosquito

control destroys homes for game birds, shorebirds, and water animals. The automobile, the mowing machine, and the grass fire are murderers of wildlife.

The protection of our diminished game supply depends upon these steps: Restore as much land to natural conditions as possible by forest, grassland, and soil conservation practices. Provide special protection to wildlife in these restored and wild areas. Aid restoration of wildlife by bringing into suitable areas animals, birds, and fish which can live there in proper balance with other animals. Limit hunting and fishing to removal of excess animals. When necessary remove competing or predatory animals to keep a good balance.

Exercise

Complete these sentences:

Real conservation of wildlife depends upon restoring the —1— of nature. Most destruction of forests by man has been to gain land for —2—, and next to use trees for —3—. —4— of forest land is privately owned. When trees are cut some should be left for —5— and to protect —6—. Trees should be harvested when —7—.

A review of the chapter

Man controls his living environment in four ways. He selects and cares for those animals which he wishes to domesticate. He improves the quality of domesticated plants and animals by selection and by breeding. He kills those plants, insects, and larger animals which are directly or indirectly harmful. He conserves those living things in the natural environment which are helpful by improving their environments and controlling their enemies. Man has discovered several chemicals effective in controlling weeds, insects, fungi, and other pests.

To improve living things it has been necessary to learn laws of inheritance and to apply them. It has been necessary to experiment with soils, crops, and foods. It has been necessary for man to be always on the alert to study the habits of his animal enemies in order to protect his crops and animals from them. And it has been necessary to develop a sense of responsibility to future generations for preserving desirable forms of life for future use. Reforestation and protection of wildlife are the responsibility of all of us if we wish to live securely in the future.

Word list for study

heredity	nematode	crop rotation	crossbreeding
variation	hybrid	predator	cambium
grafting	dominant	biological control	host
sire	mutation	fertilize	enzyme
domesticate	cutting	recessive	sperm

An exercise in thinking

Write the numbers from 1 to 40 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one of the principles. Find the one principle to which each sentence in the second list is best related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Man selects for domestication or protection those living things which have adaptations suited to his needs.

B. There is variation among the individuals of any given type of plant or animal.

C. Characteristics are transmitted from parent to offspring by heredity through the reproductive cells.

D. An egg cell is fertilized when the protoplasm of a sperm cell combines with it.

E. Man increases the yield of economically useful plants and animals by providing them with care or protection.

F. Economically helpful plants and animals are those directly useful to us or those which check our enemies.

G. Man controls economically harmful organisms by destroying them or by making their environment unsuited to their needs.

List of related ideas

1. Offspring resembles one or both parents.
2. Because weeds compete with useful plants for food and water, we must kill them.
3. Ovules develop in the part of the flower called the ovary.
4. The codling moth or apple worm is controlled by spraying.
5. The enemy of birds easiest to control is the housecat.
6. Chickens will lay in winter if they are provided warmth and light enough to find food.
7. The reproductive fluid of male fishes is called milt.
8. Songbirds live chiefly on weed seeds and insects.
9. Termites can eat wood but cannot harm stone houses.
10. We select for house plants the type of plant which requires comparatively little light.
11. We grow many house plants, such as lilies, narcissuses, and hyacinths, from bulbs.
12. The ladybird beetle is helpful to man.
13. The most important way to conserve wildlife is to protect its home.
14. The cow is the most useful all-around domestic animal.
15. The corn plant furnishes oil, sugar, starch, and fodder.
16. A hybrid is a plant or animal produced by crossing two different varieties of plants or animals.
17. Cultivating corn increases its yield from 10 to 100 times.
18. The sire is the most important animal in any herd of farm animals.

19. Grafting, which is a method of causing a branch of one tree to grow on the stem of another, is used because fruits don't breed true.
20. A hotbed, which contains fermenting manure to keep it warm, gives garden plants an early start in spring.
21. The male reproductive cell is the sperm cell.
22. The best way to get rid of flies is to destroy their breeding places.
23. A good dairy cow may give twice as much milk as a poor one.
24. The most common grass seed used for human food in this country is wheat.
25. We select the best hens by trap-nesting.
26. Dogs were probably our first domesticated animal.
27. The farm wood lot provides posts, fuel, and sometimes lumber.
28. Fertilizing soil makes better crops.
29. We improve trees by pruning or removing excess branches.
30. Large mammals are chiefly preserved in national parks and forests.
31. When cutting a forest, the best trees should be left to provide seed.
32. The mule resembles both the horse and the donkey.
33. Most hawks and owls destroy harmful rodents.
34. Contact poisons are used on insects with sucking mouth parts.
35. Ticks are removed from cattle by spraying.
36. Garden pea plants may be tall or short, and may have smooth or wrinkled seeds.
37. A young chick can develop from an egg only if the egg has been fertilized.
38. Burrowing animals can be poisoned by gas in their burrows.
39. Every plant or animal differs to some extent from every other plant and animal.
40. We put poison on plants eaten by insects with chewing mouths.

Some things to explain

1. What is meant by a perfect flower?
2. Which is more important, heredity or environment?
3. How has man upset the balance of nature?
4. Why are insects more difficult to control than are rabbits?
5. Why is conservation a larger and more difficult problem than most people think it is?
6. Why should the average person not include hunting and fishing in his plans for sport?
7. List 10 ways in which wildlife depends on soil conservation.

Some good books to read

Burbank, L., *Partner of Nature*
Bush, C. D., *Nut Grower's Handbook*
Clute, W. N., *Useful Plants of the World*
Conn, W. H., *Bacteria, Yeasts, and Molds in the Home*
Davis, H. P. and others, *Livestock Enterprises*
DuPuy, W. A., *Our Animal Friends*

and Foes
DuPuy, W. A., *Our Bird Friends and Foes*
DuPuy, W. A., *Our Insect Friends and Foes*
DuPuy, W. A., *Our Plant Friends and Foes*
Elliott, C. N., *Conservation of Natural Resources*
Hogner, D. C., *Farm Animals*
Shippen, K. B., *Great Heritage*

Film List

Introduction

MOTION PICTURE FILMS

Measurement. Encyclopedia Britannica Films Inc.
Precisely So. General Motors

FILMSTRIPS

Measurement Instruments—in the Laboratory. SVE

Chapter 1. Matter from Atom to Universe

MOTION PICTURE FILMS

Our Soil Resources. Encyclopedia Britannica Films Inc.
Matter and Energy. Coronet Instructional Films
Atomic Energy. Encyclopedia Britannica Films Inc.
Energy and Its Transformations. Encyclopedia Britannica Films Inc.
Oxygen. Coronet Instructional Films (color)
The Halogens. Coronet Instructional Films (color)
Exploring the Universe. Encyclopedia Britannica Films Inc.
Work of the Atmosphere. Encyclopedia Britannica Films Inc.

Chapter 2. Conservation of Natural Resources

MOTION PICTURE FILMS

Steel—Man's Servant. U. S. Steel (color)
Unfinished Rainbows. Aluminum Co. of America (color)
Fuels and Heat. Encyclopedia Britannica Films Inc.

Chemistry and a Changing World. Encyclopedia Britannica Films Inc.
The Magic of Coal. Bituminous Coal Institute
Evolution of the Oil Industry. U. S. Bureau of Mines
Life of the Soil. National Fertilizer Co. (color)
Conservation of Natural Resources. Encyclopedia Britannica Films Inc.

Chapter 3. Electricity and Its Uses

MOTION PICTURE FILMS

Electronics. Encyclopedia Britannica Films Inc.
Measuring Electricity. Coronet Instructional Films
Primary Cell. Encyclopedia Britannica Films Inc.
What Is Electricity? Westinghouse
Electrodynamics. Encyclopedia Britannica Films Inc.
Electrons. Encyclopedia Britannica Films Inc.

FILMSTRIPS

Wiring Wisdom. USDA
Electronics. SVE, RCA

Chapter 4. Light and Its Uses

MOTION PICTURE FILMS

The Nature of Light. Coronet Instructional Films
Light Waves and Their Uses. Encyclopedia Britannica Films Inc.
The Nature of Color. Coronet Instructional Films
The Magic of Fluorescence. General Electric
Light Is What You Make It. Better Light—Better Sight Bureau
Eyes of Science. Bausch and Lomb
Family Album. General Electric

FILMSTRIPS

Science of Seeing. General Electric

Chapter 5. Building a Healthy Body

MOTION PICTURE FILMS

Something You Didn't Eat. USDA
Strange Hunger. National Vitamin Foundation
Fundamentals of Diet. Encyclopedia Britannica Films Inc.
Digestion of Foods. Encyclopedia Britannica Films Inc.
Heart and Circulation. Encyclopedia Britannica Films Inc.
Nervous System. Encyclopedia Britannica Films Inc.
Control of Body Temperature. Encyclopedia Britannica Films Inc.

Chapter 6. Conserving Our Health

MOTION PICTURE FILMS

Posture and Personality. Encyclopedia Britannica Films Inc.
Alcohol and the Human Body. Encyclopedia Britannica Films Inc.
Help Wanted. Johnson and Johnson
Man Against Microbe. Metropolitan Life
Body Defenses Against Disease. Encyclopedia Britannica Films Inc.
This Is T. B. National T. B. Association
Body Fights Bacteria. McGraw-Hill Book Co., Inc.

FILMSTRIPS

Dairying. USDA
Robert Koch. Metropolitan Life Co.
Testing the Drinking Driver. National Conservation (sound)

Chapter 7. Machines for Modern Living

MOTION PICTURE FILMS

Horsepower. Jam Handy
Lever-Age. Shell Oil Co.
ABC of Internal Combustion. General Motors (color)
Steam Turbine. Young America Films Inc.
Simple Machines. Encyclopedia Britannica Films Inc.
Water Power. Encyclopedia Britannica Films Inc.

Chapter 8. Houses for Modern Living

MOTION PICTURE FILMS

Shelter. Encyclopedia Britannica Films Inc.
Transfer of Heat. Young America Films Inc.
Problems of Housing. Encyclopedia Britannica Films Inc.
Building America's Houses. Encyclopedia Britannica Films Inc.
Building a House. Encyclopedia Britannica Films Inc.
Trees and Homes. Weyerhaeuser
The City. Museum of Modern Art

FILMSTRIPS

Plywood Manufacture. Stillfilms

Chapter 9. Modern Methods of Transportation

MOTION PICTURE FILMS

Freight Yard. New York Central R.R.

Railroad Signals. New York Central R.R.
Airways of the Future. March of Time
Your Driving Habits. U. S. Office of Education
Caravans of Trade. Films Inc.
The Great Lakes—Highways of Commerce. Harry Grubbs
The Great Lakes—Their Link with Ocean Shipping. Harry Grubbs
Transportation. New York Central R.R.
Air in Action. Coronet Instructional Films
Arteries of the City. Encyclopedia Britannica Films Inc.
Construction of Light Airplanes. Pennsylvania State College
Problems of Flight. Encyclopedia Britannica Films Inc.
Theory of Flight. Encyclopedia Britannica Films Inc.
Jet Propulsion. General Electric

FILMSTRIPS

Inertia. National Conservation

Chapter 10. Communication in a Modern World

MOTION PICTURE FILMS

Story of Communication. Films Inc.
Sending Radio Messages. Encyclopedia Britannica Films Inc.
Receiving Radio Messages. Encyclopedia Britannica Films Inc.
Fundamentals of Accoustics. Encyclopedia Britannica Films Inc.
Sound Waves and Their Sources. Encyclopedia Britannica Films Inc.
Naturally It's F.M. General Electric
Vacuum Tubes. Encyclopedia Britannica Films Inc.
Receiving Radio Messages. Encyclopedia Britannica Films Inc.
Excursions in Science. General Electric
Sightseeing at Home. General Electric
Sound Recording and Reproduction. Encyclopedia Britannica Films Inc.
Exploring with X Rays. General Electric

FILMSTRIPS

How We Hear. Eye Gate
X Rays. General Electric

Chapter 11. Adaptations for Survival

MOTION PICTURE FILMS

Life in a Drop of Water. Coronet Instructional Films
Earthworms. United World Films

Story of the Bee. United World Films
Growth of Flowers. Coronet Instructional Films
The Cell. Coronet Instructional Films
Life of Plants. Castle
Plant Growth. Encyclopedia Britannica Films Inc.
Reactions in Plants and Animals. Encyclopedia Britannica Films Inc.
Sunfish. Encyclopedia Britannica Films Inc.
Killers. Teaching Film Custodians Inc.

Filmstrips

Anatomy of the Honeybee. USDA

Chapter 12. Conservation of Living Things

Motion picture films

Heredity. Encyclopedia Britannica Films Inc.
Forests and Conservation. Coronet Instructional Films (color)
Green Harvest. Weyerhouser (color)
Life Blood of the Land. Castle
Science of Milk Production. Purina
White Pine Blister Rust. Castle
Animals in Modern Life. Encyclopedia Britannica Films Inc.
Fungus Plants. Encyclopedia Britannica Films Inc.
Reproduction Among Mammals. Encyclopedia Britannica Films Inc.
Growth of Flowers. Coronet Instructional Films
Science and Agriculture. Encyclopedia Britannica Films Inc.

Filmstrips

Improvement of Plants and Animals through Breeding. Nasco
Propogation of Trees and Shrubs by Vegetative Means. USDA
Nature of Plant Diseases. USDA
Saving Our White Pines from Blister Rust. USDA
How to Get Rid of Rats. USDA
Soil Conservation Benefits Wildlife. USDA
Soil and Water Conservation by the Beaver. USDA

Where Visual Aids May Be Obtained

Below are the addresses of the sources where the film or filmstrip listed above may be obtained.

Bausch and Lomb Optical Co., 635 S. St. Paul St., Rochester 2, N. Y.

Better Light—Better Sight Bureau, 420 Lexington Ave., New York 17

Castle Films Division, United World Films, Inc., 1445 Park Ave., New York; or Field Building, 135 S. La Salle St., Chicago 3, Ill.; or Russ

Building, San Francisco 4, Calif.

Coronet Instructional Films, 65 E. South Water St., Chicago 1, Ill.; or 207 E. 37th St., New York 16.

Encyclopedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill.

Eye Gate House, Inc., 303 E. 71 St., New York 2

Films, Inc., 330 W. 42nd St., New York 18

General Electric Co., Lamp Dept., Nela Park, Cleveland 12, Ohio

General Electric Co., Visual Education Division, 1 River Road, Schenectady 5, N. Y.

General Motors Corp., Dept. of Public Relations Film Distribution Section, 3044 W. Grand Blvd., Detroit 2, Mich.; or 405 Montgomery St., San Francisco 4, Calif.

Harry Grubbs, Hollywood Film Enterprises, Inc., 6040 Sunset Blvd., Hollywood 28, Calif.

The Jam Handy Organization, 2821 E. Grand Blvd., Detroit 11, Mich.

Johnson and Johnson, Promotion Dept., New Brunswick, N. J.

March of Time Forum Films, 369 Lexington Ave., New York 17

McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 18

Metropolitan Life Insurance Co., 1 Madison Ave., New York 10; or 600 Stockton St., San Francisco, Calif.

Museum of Modern Art, Film Library, 11 W. 53rd St., New York 19

National Fertilizer Assn., 616 Investment Bldg., Washington 5, D. C.

National Tuberculosis Association, 1790 Broadway, New York 19

New York Central System, Motion Picture Bureau, 466 Lexington Ave., New York 17

Pennsylvania State College Audio-Visual Aids Library, State College, Pa.

Ralston Purina Co., 835 S. 8th St., St. Louis, Mo.

RCA, 30 Rockefeller Plaza, New York 20

Shell Oil Co., Public Relations Dept., 50 W. 50th St., New York 20

Stillfilm, Inc., 171 South Los Robles, Pasadena 5, Calif.

Society for Visual Education, Inc. 1345 W. Diversey Parkway, Chicago 14, Ill.

U. S. Bureau of Mines, Dept. of the Interior, Washington 25, D. C.

U. S. Department of Agriculture, Extension Service, Washington 25, D. C.

U. S. Office of Education, Washington 25, D. C.

U. S. Steel Corp. of Delaware, 436 Seventh Ave., Pittsburgh 30, Pa.

Westinghouse Electric Corp., School Service, 306 Fourth Ave., P. O. Box 1017, Pittsburgh 30, Pa.

Weyerhaeuser Sales Co., First National Bank Bldg., St. Paul 1, Minn.

Young America Films, Inc., 18 E. 41st St., New York 17

GLOSSARY

KEY TO SOUNDS OF WORDS

ā as in āble	ē as in ēve	ō as in ōld
ȧ as in chȧotic	ė as in ėvent	ȯ as in ȯbey
â as in câre	ĕ as in ĕnd	ô as in ôrb
ă as in ădd	ĕ as in silĕnt	ŏ as in ŏdd
ă as in ăccount	ẽ as in makẽr	ŏ as in sŏft
ä as in ärm		ŏ as in cŏnnect
ȧ as in ȧsk	ī as in īce	
ȧ as in sofȧ	ĭ as in ĭll	o͞o as in fo͞od
	ĭ as in charĭty	o͝o as in fo͝ot
ou as in out		
oi as in oil	ū as in cūbe	ch as in chair
	ů as in ůnite	g as in go
	û as in ûrn	ng as in sing
	ŭ as in ŭp	th as in then
	ŭ as in circŭs	th as in thin
	ü as in menü	tū as in natūre
		dū as in verdūre
		y as in yet
		zh = z as in azure

The accented syllable is marked ′. ′ shows a secondary accent.

acid (ăs′ĭd): a chemical substance, sour and sharp to the taste

acid (ăs′ĭd) **hypo** (hī′pȯ): a chemical solution used in photography to stop the development of the image and dissolve from the film or paper the undeveloped silver salts

adaptation (ăd′ăp·tā′shŭn): the structures and types of behavior which enable organisms to live under certain conditions

adolescence (ăd′ȯ·lĕs′ĕns): the period of growth during which boys and girls become men and women

adrenal (ăd·rē′năl): a ductless gland located above the kidney

ailerons (ā′lẽr·ŏnz): the hinged wing flaps used to keep the wings of airplanes level or to cause the airplane to roll

airfoil (âr′foil′): any surface designated to create and use differences in the pressure of moving air

alcohol (ăl′kȯ·hŏl): a colorless, inflammable, and poisonous liquid chemical produced from sugar fermented by yeasts

algae (ăl′jē): the simplest plants capable of manufacturing their own food, many of which are composed of only one cell

alimentary (ăl′ĭ·mĕn′tȧ·rĭ) **canal** (kȧ·năl′): the duct or long tube—the mouth, gullet, stomach, intestines—through which food is passed during the process of digestion

alternating (ôl′tẽr·nāt′ĭng) **current** (kûr′ĕnt): an electric current in which the electrons flow in one

direction and then in the other direction

altimeter (ăl·tĭm′ē·tẽr): a device for measuring the altitude of an airplane

ampere (ăm′pēr): the unit of measurement of the flow of an electric current

amphibian (ăm·fĭb′ĭ·ăn): an animal which spends part of its life in water and part on land

amplifier (ăm′plĭ·fī′ẽr): a radio tube or device used to build up the strength of a current or sound

amplitude (am′plĭ·tūd): the extent of the swing of a vibrating body or the distance from the beginning to the crest of a wave; the current or voltage of an alternating current or high frequency circuit at any instant

anesthetic (ăn′ĕs·thĕt′ĭk): a drug which causes loss of feeling

anneal (ă·nēl′): to temper or toughen glass or steel by heating and slow cooling

antibody (ăn′tĭ·bŏd′ĭ): a chemical produced by the body which makes it a poor environment for germs

antiseptic (ăn′tĭ·sĕp′tĭk): a drug used to slow or prevent the growth of bacteria in wounds

antitoxin (ăn′tĭ·tŏk′sĭn): a substance in the blood of people who have had a disease and have overcome the toxins produced by the disease germs

aperture (ăp′ẽr·tūr): the opening in a camera through which light is admitted

appendage (ă·pĕn′dĭj): an external organ, as the leg or a feeler of an animal

arc (ärk): a gap between two carbon rods which is filled with gas heated by electricity

armature (är′mȧ·tūr): any object that is attracted by an electromagnet

artery (är′tẽr·ĭ): a blood vessel carrying blood from the heart to the body

arthropod (är′thrō·pŏd): an animal with jointed legs and an outside skeleton; the insect group

artificial (är′tĭ·fĭsh′ăl) **respiration** (rĕs′pĭ·rā′shŭn): a process of alternately applying and releasing pressure on the body of a patient to restore normal breathing

astigmatism (ȧ·stĭg′mȧ·tĭz′m): a condition caused by irregularities in the shape of the lens or cornea of the eye

astronomy (ăs·trŏn′ō·mĭ): the scientific study of the stars, planets, and all other bodies in space

atom (ăt′ŭm): the smallest part of an element. Molecules are made up of *atoms*.

atomizer (ăt′ŭm·īz′ẽr): a device used for changing a liquid to a spray by forcing the liquid through a small opening

bacillus (bȧ·sĭl′ŭs): a rod-shaped bacterium

ball (bôl) **bearing** (bâr′ĭng): a type of support for an axle. A *ball bearing* contains steel balls to reduce friction.

base (bās): a compound which will react with acids and produce a chemical salt

battery (băt′ẽr·ĭ): a number of electric cells connected together to produce an electric current

bile (bīl): a bitter fluid secreted by the liver. *Bile* aids in the digestion of fats in the small intestines

biological (bī′ō·lŏj′ĭ·kăl) **control** (kŏn·trōl′): the control of harmful pests by permitting other living things to live on them

biology (bī·ŏl′ō·jĭ): the scientific study of all living things

brake (brāk) **shoe** (shōō): the part of a brake that presses on the wheel

brush (brŭsh): a device which provides contact with the rotating part of an electric motor

by-product (bī′-prŏd′ŭkt): a material or substance produced during the making of a product but not related to the main product

caffein (kăf′ē·ĭn): a stimulating drug present in coffee

calcium (kăl′sĭ·ŭm): the element in lime used most abundantly in the body

calorie (kăl′ō·rĭ): a unit for measuring heat; the amount of heat required to raise one gram of water one degree centigrade

Calorie (food) (kăl′ō·rĭ): 1000 small calories

calorimeter (kăl′ō·rĭm′ē·tẽr): a device used to measure the amount of heat given off by burning materials

cambium (kăm′bĭ·ŭm): the part of a plant stem, from which growth proceeds, between the bark and the wood

capillary (kăp′ĭ·lĕr′ĭ): a minute blood vessel which carries blood among the body cells uniting the arteries and veins

carbohydrates (kär′bō·hī′drāts): the sugars and starches; the foods containing carbon, hydrogen, and oxygen

carbon (kär′bŏn) **monoxide** (mŏn-ŏk′sīd): a colorless, odorless, tasteless, and deadly poisonous gas produced by incomplete burning. *Carbon monoxide* is present in the exhaust of a gas engine.

carburetor (kär′bū·rā′tẽr): a device in a gasoline engine which mixes gasoline with air

cellulose (sĕl′ū·lōs): a wood material used in making rayon, cellophane, etc.

centigrade (sĕn′tĭ·grād): a thermometer scale which marks 100 degrees between the freezing point of water marked 0° and the boiling point marked 100°

centimeter (sĕn′tĭ·mē′tẽr): the one hundredth part of a meter; .3937 inches

centrifugal (sĕn·trĭf′ū·găl): flying or proceeding from the center

centrifugal (sĕn·trĭf′ū·găl) **force** (fōrs): the outward push or pull exerted by a rotating object

cerebellum (sĕr′ē·bĕl′ŭm): the smaller back part of the brain

cerebrum (sĕr′ē·brŭm): the largest part of the brain; the center of thinking and voluntary action in the brain

charge (chärj): a quantity of electrical pressure

chemical (kĕm′ĭ·kăl): any substance produced by a chemical process or used in producing a chemical effect; any pure material

chemistry (kĕm′ĭs·trĭ): the science which collects, studies, and explains the composition of matter

and the changes that take place in substances

chlorophyll (klō′rô·fĭl): the green coloring matter of plants

chronometer (krô·nŏm′ê·tẽr): a clock used on board ship to find longitude

cloverleaf (klō′vẽr·lēf′): an intersection at which one road passes above another with turnoffs provided to prevent left-hand turns

clutch (klŭch): the coupling for throwing the working parts of an automobile or other machine into action

coccus (kŏk′ŭs): round-shaped bacteria

code (kōd): a system of symbols used instead of words in communication; the dots and dashes in telegraphy

coke (kōk): a solid fuel produced from coal by heating it with insufficient air so that burning is incomplete

community (kŏ·mū′nĭ·tĭ): an area in which many different living things live together dependent somewhat upon one another

commutator (kŏm′ū·tā′tẽr): a device in a direct current generator or motor used to conduct current to or from the rotor

compass (kŭm′pȧs): a free-moving magnetized needle that points toward the north magnetic pole

composition (kŏm′pô·zĭsh′ŭn): a made material, such as roofing, floor, or wall covering, made of wood pulp, plant or rock fibers, etc.

compound (kŏm′pound): a chemical substance made up of more than one element

concave (kŏn′kāv): hollow and rounded, like the inside of a bowl of a round spoon

conclusion (kŏn·klōō′zhŭn): a scientific decision made after thorough study and experiment

concrete (kŏn′krēt): an artificial stone made by mixing cement, sand, gravel, and water

condenser (kŏn·dĕn′sẽr): a lens or reflector for concentrating light; a device which stores electrical charges

conductor (kŏn·dŭk′tẽr): any material through which electricity or heat will travel

conservation (kŏn′sẽr·vā′shŭn): the process of efficient use and the preservation for later use of all our store of natural things such as water, minerals, soil, and living things that exist on the earth

contagious (kŏn·tā′jŭs): can be transmitted from person to person

contraction (kŏn·trăk′shŭn): the process of shrinking or drawing together

contour (kŏn′tŏŏr) **plowing** (plou′ĭng): plowing that follows the side of a slope or hill at the same elevation

control (kŏn·trōl′): something a scientist keeps in his experiment for comparison

convection (kŏn·vĕk′shŭn): the transfer of heat by means of currents in liquids and gases

convex (kŏn′vĕks): rounded outward like the outside of the bowl of a round spoon

conveyer (kŏn·vā′ẽr): a machine often consisting of a belt or chain passing over pulleys used to carry materials

crane (krān): a device used to lift heavy loads and move them

crank (krăngk): the lever or bar attached to a piston and to the shaft of a flywheel

crop (krŏp) **rotation** (rō·tā′shŭn): the planting of a different kind of crop in a certain area each year

cross (krŏs) **breeding** (brēd′ĭng): mating or crossing plants or animals, having different traits, in order to develop new plants or animals that will have the desired combinations of traits

crustacean (krŭs·tā′shăn): the large class of animals that has a hard outside shell and jointed legs; lobsters, crabs, etc.

current (kûr′ĕnt): the flow of electrons

cutting (kŭt′ĭng): the leafy part of a growing stem which has been cut off and planted in water or moist soil to root

cylinder (sĭl′ĭn·dẽr): the hollow round metal tube through which the piston moves in a machine

decibel (dĕs′ĭ·bĕl): the unit of measurement of sound

design (dē·zīn′): a plan or pattern for making an article

detergent (dē·tûr′jĕnt): a substance having the ability to break up dirt or fats in water; a soaplike chemical

developer (dē·vĕl′ŭp·ẽr): a solution of chemicals used to bring out the image on photographic film or paper

dextrose (dĕks′trōs): a simple sugar sometimes made from starch by heating it with acids

Diesel (dē′zĕl): an internal combustion engine which fires fuel by compression

differential (dĭf′ẽr·ĕn′shăl): a set of bevel gears in the middle of the automobile axle that permits the rear axles to turn independently when rounding a curve

diffuse (dĭ·fūz′): to cause to spread out in all directions; to scatter

diffusion (dĭ·fū′zhŭn): the mixing together of molecules of different materials because of their motion; the scattering of light

direct (dĭ·rĕkt′) **current** (kûr′ĕnt): an electric current in which the electrons always move in one direction

distill (dĭs·tĭl′): to heat and collect the vapors that pass off from a substance

domesticate (dō·mĕs′tĭ·kāt): to tame and keep in captivity; to develop wild plants and animals for use

dominant (dŏm′ĭ·nănt): the quality of the traits which appear most frequently in crossbreeding

drag (drăg): all the forces which tend to hold back or pull or drag an airplane down

ductless (dŭkt′lĕs) **glands** (glăndz): the organs of the body that produce chemicals necessary for the body to function

eccentric (ĕk·sĕn′trĭk): a wheel with its axle off center. An *eccentric* changes the position of the slide valve in an engine.

efficiency (ĕ·fĭsh′ĕn·sĭ): the amount of energy or work turned out by a machine or device divided by

the total amount of energy put into the machine

elastic (ē·lăs′tĭk): capable of recovering size or shape after being changed by pulling or pressure

electrocardiograph (ē·lĕk′trō·kär′dĭ·ō·gräf′): a chart used by doctors to learn the condition of a patient's heart

electromagnet (ē·lĕk′trō·măg′nĕt): a magnet made by surrounding a bundle of iron rods—a core—by a coil of wire through which an electric current can pass

electron (ē·lĕk′trŏn): a negatively charged energy particle in an atom

electron (ē·lĕk′trŏn) **gun** (gŭn): a device used in television which shoots a narrow beam of electrons through the space inside a glass vacuum tube

electronics (ē·lĕk′trŏn′ĭks): the branch of science which uses free electrons to do useful work

emotion (ē·mō′shŭn): a deep feeling; an inner urge to act

emulsion (ē·mŭl′shŭn): a mixture of silver salts in gelatin with which film is coated; a permanent suspension

enlarger (ĕn·lär′jẽr): a projector used for reproducing the image from a negative in magnified form on photographic paper

environment (ĕn·vī′rŭn·mĕnt): all those things and forces in the midst of which an organism lives

enzyme (ĕn′zīm): a chemical produced by a living thing for the digestion of food

epidemic (ĕp′ĭ·dĕm′ĭk): a period when infectious or contagious disease attacks many people at the same time

erosion (ē·rō′zhŭn): the process of changes made in the earth's surface by running water, movement of glaciers, temperature changes, wind, waves, etc.

exhaust (ĕg·zôst′): a pipe through which steam or burned gasses are forced out of an engine

facsimile (făk·sĭm′ĭ·lē): a process used in printing newspapers by radio

fatigue (fȧ·tēg′): tiredness to the point of exhaustion

fertilize (fûr′tĭ·līz): to unite a sperm cell with an egg cell

fertilizer (fûr′tĭ·līz′ẽr): any chemical or other material added to soil to supply growing plants with needed minerals

fiberboard (fī′bẽr·bōrd′): a lumber-like material made from wood fiber

field (fēld) **magnet** (măg′nĕt): an electromagnet used in the outer part of a dynamo or motor

film (fĭlm) **reader** (rēd′ẽr): a device used for projecting film positives of printed materials on a diffusing glass screen

filter (fĭl′tẽr): a device used to take the dust from the air in a hot-air heating system; colored glass used in taking pictures

fluid (flo͞o′ĭd) **coupling** (kŭp′lĭng): a clutch or coupling operated by the use of flowing oil

fluorescent (flo͞o′ō·rĕs′ĕnt): giving off a light different in color from the substance itself in ordinary light

flywheel (flī′hwēl′): a wheel with a

heavy rim used to give an engine constant speed

focus (fō′kŭs): to bring light rays from an object together at a point

foot (fo͝ot) **candle** (kăn′d'l): the brightness of light produced by a certain standard candle at a distance of one foot; the unit of brightness

force (fōrs): a push or a pull; energy applied to move something

formula (fôr′mū·lȧ): a group of letters and numbers used to indicate the kind and number of elements in a chemical compound

frequency (frē′kwĕn·sĭ): the number of crests of sound waves passing a fixed point in one second

fulcrum (fŭl′krŭm): the point or support around which a lever turns

functional (fŭngk′shŭn·ăl): that which best serves the purpose for which it is intended

fungi (fŭn′jī): a group of simple plants, containing no chlorophyll, which obtains food from either living or dead material

fuse (fūz): a device placed in an electric circuit which melts when the current increases beyond a safe point

fuselage (fū′zĕ·lĭj): the body of an airplane

f value: the product obtained by dividing the focal length of the lens by its diameter. The size of the aperture is indicated by the f number.

galaxy (găl′ăk·sĭ): any huge group of a billion or more stars, star clusters, and other bodies in the universe

galvanometer (găl′vȧ·nŏm′ê·tẽr): a sensitive meter for detecting a weak electric current

ganglia (găng′glĭ·ȧ): certain nerve centers in the spinal cord which control reflex acts

gastric (găs′trĭk) **juice** (jo͞os): the fluid of the stomach which is one of the chief chemicals in digestion of food

geology (jê·ŏl′ô·jĭ): the scientific study of the earth's composition, structure, age, etc., as shown in the rocks

gland (glănd): a chemical-producing organ in the body

glare (glâr): the result of any light shining directly into the eyes

governor (gŭv′ẽr·nẽr): a device which regulates the speed of an engine

grafting (gråft′ĭng): joining a branch of one tree upon the stem of another in such a way that the branch will grow

gravity (grăv′ĭ·tĭ) **ventilation** (vĕn′-tĭ·lā′shŭn): a system in which the air is moved by difference in temperature; convection ventilation

great (grāt) **circle** (sûr′k'l): the shortest distance between two points on the globe or two cities on the earth

grid (grĭd): the wire screen between the filament and plate in a radio tube

grounded (groun′dĕd): connected with the earth so as to complete an electric circuit

gully (gŭl′ĭ): a small valley started by running water

gyroscope (jī′rô·skōp): a heavy rotating wheel which resists being

turned, thus keeping the controls of an airplane steady

helicopter (hĕl′ĭ·kŏp′tẽr): an airplane supported by propellers turning in a horizontal plane

heredity (hē·rĕd′ĭ·tĭ): the passing of traits from one generation to another

horsepower (hôrs′pou′ẽr): the unit for measuring the rate of doing work

host (hōst): a plant or animal on which another plant or animal lives as a parasite

humus (hū′mŭs): the black or brown material in soil which comes from partially decayed plants

hybrid (hī′brĭd): a plant or animal developed through crossing two varieties or species of plants or animals

hydraulic (hī·drô′lĭk) **press** (prĕs): a device or machine used for producing great force by using the resistance of liquids to pressure

hypothesis (hī·pŏth′ē·sĭs): an idea that is to be tested scientifically

igneous (ĭg′nē·ŭs): heat-formed

immunity (ĭ·mū′nĭ·tĭ): the resistance to disease

incandescence (ĭn′kăn·dĕs′ĕns): glowing whiteness of a material caused by intense heat

incandescent (ĭn′kăn·dĕs′ĕnt): hot enough to give off light

incidence (ĭn′sĭ·dĕns): The angle at which light falls on a reflecting surface is the angle of *incidence.*

inclined (ĭn·klīnd′) **plane** (plān): a sloping surface

indirect (ĭn′dĭ·rĕkt′): not descending in a straight line. Light that is reflected from the ceiling downward into the room is *indirect.*

induced (ĭn·dūst′) **current** (kûr′ĕnt): an electric current or magnetism produced by the force of a magnetic field in the vicinity

induction (ĭn·dŭk′shŭn) **coil** (koil): a device used to change a direct current to an alternating current of different voltage

inertia (ĭn·ûr′shȧ): the resistance of all matter to being moved or to being stopped when once in motion

infectious (ĭn·fĕk′shŭs): likely to cause disease

infrared (ĭn′frȧ·rĕd′) **rays** (rāz): invisible heat rays from the sun

inoculate (ĭn·ŏk′ū·lāt): to insert into the skin disease germs or chemicals which enable the body to become immune to disease

instinct (ĭn′stĭngkt): a natural tendency to do certain things; unlearned action

insulin (ĭn′sū·lĭn): a medicine used in the treatment of diabetes

intelligence (ĭn·tĕl′ĭ·jĕns): the ability to change behavior so as to find satisfactory solutions to problems

internal (ĭn·tûr′năl) **combustion** (kŏm·bŭs′chŭn): the development of power by burning or exploding fuel within an engine, as in a gas engine

intestine (ĭn·tĕs′tĭn): the tubular part of the digestive system connecting the stomach with the outside of the body; the bowels

intoxication (ĭn·tŏk′sĭ·kā′shŭn): ex-

cited or stupefied state produced by drinking alcohol

inversely (ĭn·vûrs′lĭ): in opposite order

involuntary (ĭn·vŏl′ŭn·tĕr′ĭ): not controlled by the will

irritability (ĭr′ĭ·tȧ·bĭl′ĭ·tĭ): the ability to respond to a stimulus

jet (jĕt) **engine** (ĕn′jĭn): an engine in which burning fuel shoots backwards so fast that the engine is pushed forward

kidney (kĭd′nĭ): one of the organs of the body which filters waste out of the blood

kiln (kĭl): a large oven for drying, burning, or hardening bricks or other materials

kilocycle (kĭl′ŏ·sī′k′l): one thousand cycles. A *kilocycle* refers to frequency of radio waves or alternating current.

kilogram (kĭl′ŏ·grăm): 1000 grams in the metric system; about 2.2 pounds

kilowatt (kĭl′ŏ·wŏt′) **hour** (our): 1000 watts of electricity flowing for one hour

kinetic (kĭ·nĕt′ĭk): the energy possessed by moving objects

lath (låth): a strip of wood or wire netting used as a surface for applying plaster

lathe (lāth): a machine used for turning or giving a round shape to articles of wood, metal, etc.

laxative (lăk′sȧ·tĭv): any material used to hasten the elimination of waste from the bowels

lens (lĕnz): a piece of glass having one or both surfaces curved so as to change the apparent size of an object seen through it

lever (lē′vẽr): a rigid bar which turns about a point called a fulcrum

lichen (lī′kĕn): a scalelike plant that grows on rocks or bark of trees

lift (lĭft): the force which causes airplanes to rise

ligament (lĭg′ȧ·mĕnt): a cordlike tissue that holds the movable bones together

light (līt) **valve** (vălv): a valve through which light shines upon a sensitive film or electronic tube

loam (lōm): a soil made of a mixture of rock materials and humus

lock (lŏk): a canal with gates at both ends

lymph (lĭmf): a liquid which passes to the cells from the blood vessels

machine (mȧ·shēn′): a device used to apply force to good advantage

magnet (măg′nĕt): a piece of magnetized metal having the power to attract iron

magnetic (măg·nĕt′ĭk) **field** (fēld): the total number of lines of force around the poles of a magnet or around an electric current

magnify (măg′nĭ·fī): to increase the apparent size of an object

malnutrition (măl′nū·trĭsh′ŭn): a physical condition resulting from the lack of essential foods containing necessary energy, minerals, or vitamins

mammal (măm′ăl): a class of animals in which the female produces milk to feed her young

mantle (măn′t'l): a hollow cone woven from cloth materials and dipped in chemicals which give off light when hot enough

mass (măs): the amount of matter in an object

measurement (mězh′ẽr·měnt): a method of comparing something with a standard unit such as a foot, quart, etc.

mechanical (mē·kăn′ĭ·kăl) **advantage** (ăd·vȧn′tĭj): the number of times a machine multiplies the force put into it

medulla (mē·dŭl′ȧ): the part of the brain that connects with the spinal cord

membrane (měm′brān): a thin skin or tissue which covers or lines various organs of the body

metabolism (mě·tăb′ō·lĭz'm): the whole process of using food and releasing energy from it within the organism

metamorphic (mět′ȧ·môr′fĭk): changed in form by pressure, heat, etc.

meter (mē′tẽr): a device for measuring especially the rate of motion or flow; also a unit of measure equaling about 39.4 inches

modulation (mŏd′ū·lā′shŭn): a change in the frequency or strength of a current or radio wave

molecule (mŏl′ē·kūl): the smallest part of any kind of material

mollusks (mŏl′ŭsks): soft-bodied animals mostly living in shells and in or near water

multiplex (mŭl′tĭ·plěks): pertaining to a system used in telegraphy for sending two or more messages at the same time

mutation (mū·tā′shŭn): a natural process by which plants with new characteristics or traits are produced

narcotic (när·kŏt′ĭk): a drug that reduces the activity of parts of the brain

natural (năt′ū·răl) **resources** (rē·sōrs′ěz): all the natural things on the earth—forests, water, minerals, soil, living things, etc.

navigation (năv′ĭ·gā′shŭn): the setting up of a course for a ship or airplane and the directing of the vessel on its course

nematode (něm′ȧ·tōd): a small round worm, often a parasite

neon (nē′ŏn): a gas element that glows red when heated

neurosis (nū·rō′sĭs): a mild form of mental illness

neutron (nū′trŏn): one of the energy particles in an atom

nichrome (nī′krōm): an alloy that withstands high temperatures and resists oxygen well, used in making wire for electrical heating devices

nitrifying (nī′trĭ·fī′ĭng): adding nitrogen to the soil

nucleus (nū′klē·ŭs): the central part of an atom containing the neutrons and protons; the central part of a living cell

ohm (ōm): the unit of measurement of the resistance to electric pressure

opaque (ō·pāk′): incapable of transmitting a visible amount of light

orbit (ôr′bĭt): the nearly circular path of the earth or any other body around the sun

ore (ōr): any mineral substance mined from the earth from which metals and some nonmetals are obtained

organic (ôr·găn′ĭk): derived from living things

osmosis (ŏs·mō′sĭs): the process by which water passes through the walls of root hairs or other membrane

overproduction (ō′vẽr·prō·dŭk′shŭn): production of more individuals than the environment can support

pancreas (păn′krē·ăs): the fleshy gland near the stomach which supplies one of the digestive juices

parallel (păr′ă·lĕl): *Parallel* connections of electric cells run from positive to positive and negative to negative poles.

parasite (păr′ȧ·sīt): any organism using living matter for food

patent (păt′ĕnt) **medicines** (mĕd′ĭ·sĭnz): substances sold at drugstores that are supposed to cure ailments of the human body

pedestrian (pē·dĕs′trĭ·ăn): a person travelling on foot

pendulum (pĕn′dū·lŭm): a weight supported by a string or wire so it can swing freely

percussion (pẽr·kŭsh′ŭn): striking. *Percussion* musical instruments have to be struck to produce sound.

perspiration (pûr′spĭ·rā′shŭn): moisture given off from the body through the sweat glands; sweat

petroleum (pē·trō′lē·ŭm): a crude mineral oil

phosphorus (fŏs′fō·rŭs): a mineral necessary to the growth of living cells

photoelectric (fō′tō·ē·lĕk′trĭk) **cell** (sĕl): a device containing a metal or compound that gives off electrons when light shines upon it; a device used for measuring light

photoflood (fō′tō·flŭd′): a Mazda lamp with a short, thick filament which gives an intensely bright light

photosynthesis (fō′tō·sĭn′thē·sĭs): the process of food-making in plants

phototube (fō′tō·tūb′): a device similar to a photoelectric cell used to carry current

physics (fĭz′ĭks): the scientific study of physical changes of matter

piston (pĭs′tŭn): the moving part in the cylinder of a machine

pitch (pĭch): the highness or lowness of sound

planet (plăn′ĕt): any large body in space, except a comet, revolving in a nearly circular path around the sun

plasma (plăz′mȧ): the nearly colorless, liquid part of the blood in which the corpuscles float

plate (plāt): the positively charged metal plate in a radio tube

plywood (plī′wood′): lumber consisting of thin layers of wood glued and pressed together

Polaroid (pō′lẽr·oid): a material that absorbs light waves travelling in certain directions

potential (pō·tĕn′shăl): stored, as energy stored in a body

power (pou′ẽr): the ability to do work; the amount of work done in a definite amount of time

precipitation (prē·sĭp′ĭ·tā′shŭn): condensed water vapor that falls to the earth in the form of rain, hail, or snow

predator (prĕd′ȧ·tōr): an animal that captures and eats other animals

projector (prō·jĕk′tẽr): a device for reproducing pictures on a screen in a magnified form from a film or negative

property (prŏp′ẽr·tĭ): the essential individual characters of a substance

proton (prō′tŏn): one of the particles in an atom which contains positive electrical charges

protoplasm (prō′tō·plăz'm): the complex chemical of which all living organisms are constructed; living matter

protozoa (prō′tō·zō′ȧ): one-celled animals, generally larger than bacteria

psychiatrist (sī·kī′ȧ·trĭst): a doctor who treats mental illness

psychosis (sī·kō′sĭs): a functional mental illness causing the victim to behave strangely

quack (kwăk): any doctor who has only one system of treatment for all diseases

radar (rā′där): a device which uses a reflected radio wave to make a picture

radiant (rā′dĭ·ănt): giving off rays of light or heat

rarefaction (râr′ē·făk′shŭn): a thin layer in the air produced by movement of molecules striking each other when a sound wave is being produced

reaction (rē·ăk′shŭn) **time** (tīm): the time it takes a person to act after he realizes he should

recessive (rē·sĕs′ĭv): the quality of the traits which appear least frequently in crossbreeding

rectifier (rĕk′tĭ·fī′ẽr): a device for changing an alternating current to direct current

red (rĕd) **corpuscles** (kôr′pŭs·'lz): minute red cells in the blood which carry oxygen

reflect (rē·flĕkt′): to turn or direct back from a surface

reflex (rē′flĕks): a simple unlearned act

refract (rē·frăkt′): to bend light rays by passing them from one material to another

relay (rē·lā′): a device used in telegraphy to make possible sending telegrams long distances

reptile (rĕp′tĭl): an animal with a backbone, scaly skin, and short legs or none

research (rē·sûrch′): an experimental method of studying complex problems

resistance (rē·zĭs′tăns): the force opposing efforts to move objects

resonance (rĕz′ō·năns): resounding; the prolonging or increasing of sound by sympathetic vibrations

rotor (rō′tẽr): coils of wire which move through the magnetic field of the field magnets in a dynamo or motor

rudder (rŭd′ẽr): the guiding or

steering part of an airplane or boat

safety (sāf′tĭ) **valve** (vălv): a valve used to release steam in a boiler to prevent an explosion

saliva (sȧ·lī′vȧ): the digestive juice in the mouth

salt (sôlt): any chemical formed by action of a metal or base with an acid or acid-forming element

saprophyte (săp′rȯ·fīt): an organism that lives off dead matter or material

sedimentary (sĕd′ĭ·mĕn′tȧ·rĭ) **rock:** rock formed from layers of materials that have settled in bodies of water

series (sẹ̄r′ēz): an arrangement of things in one continuous order, as of lamps or cells. *Series* connections run from positive to negative to positive to negative poles, etc.

serum (sẹ̄r′ŭm): a fluid obtained from an organism which has become immune to a disease

sextant (sĕks′tănt): an instrument used by sailors to find latitude

shaft (shȧft) **mining** (mīn′ĭng): obtaining ore from a deep well-like hole at the bottom of which tunnels are run on the level to the source of ore

shellac (shĕ·lăk′): a liquid made of resins dissolved in alcohol

shutter (shŭt′ẽr): a set of metal plates in front of the lens in a camera which opens and closes

sidereal (sī·dẹ̄r′ē·ăl) **time** (tīm): time obtained by observing a star

sire (sīr): the male parent

slip (slĭp) **rings** (rĭngz): contact rings at the end of the rotor in an electric generator or motor

solar (sō′lẽr): anything relating to or produced by the sun

solar (sō′lẽr) **house** (hous): a house built to make use of heat and light from the sun

solvent (sŏl′vĕnt): a substance, usually a liquid, in which another material is dissolved

sound (sound) **track** (trăk): a series of lines of different lengths and sizes printed on the edge of a film for producing sound

specific (spē·sĭf′ĭk) **gravity** (grăv′ĭ·tĭ): relative weight of an object compared with the weight of an equal volume of water

specific (spē·sĭf′ĭk) **drug** (drŭg): a drug which cures a certain disease

spectroscope (spĕk′trȯ·skōp): a device used to identify an element by the color seen in the light it gives off in its hot, gaseous state

spectrum (spĕk′trŭm): rainbow colors

sperm (spûrm): the male cell of a plant or animal necessary for reproduction

spirochete (spī′rȯ·kēt): a spiral or long and twisted type of bacteria

splint (splĭnt): a series of rods or boards bound around a broken leg or arm with strips of cloth

sprocket (sprŏk′ĕt): a toothlike projection on a wheel

state (stāt): the nature or condition of matter

static (stăt′ĭk): standing still; electricity stored in a nonconductor

sterile (stĕr′ĭl): without germs

stethoscope (stĕth′ȯ·skōp): a listening device used by doctors to study the conditions of the heart or lungs

stimulant (stĭm′ū·lănt): a drug used to keep one awake or active

stimulate (stĭm′ū·lāt): to irritate or excite to greater activity

stimulus (stĭm′ū·lŭs): that which causes an organism to act

stoker (stōk′ẽr): a machine that feeds coal into the furnace automatically

storage (stōr′ĭj) **cell** (sĕl): a device for storing chemical energy to provide electric current

streamlined (strēm′līnd′): shaped so that air or water flows around it smoothly

strip (strĭp) **mining** (mīn′ĭng): mining by removing surface soil and digging ore with power shovels; open-pit mining

stucco (stŭk′ō): a kind of plaster used for outside walls

sunspots (sŭn′spŏts′): cool areas that pass across the face of the sun appearing periodically as large, dark, irregular patches

suspension (sŭs·pĕn′shŭn): held up by cables or other means; hanging

symbol (sĭm′bŭl): one or more letters or figures used instead of a name

teletype (tĕl′ē·tīp): a system by which typewritten telegrams are sent and received

tendon (tĕn′dŭn): a cordlike fibrous tissue joining a large muscle to a bone

terrace (tĕr′ĭs): one of a series of earth banks on a slope following the contour of the slope

thallus (thăl′ŭs): the group of plants including both the fungi and algae

theory (thē′ō·rĭ): a scientific conclusion based upon considerable information or evidence

thermocouple (thûr′mō·kŭp′′l): a device of joined metals used for measuring temperature in a furnace

thermostat (thûr′mō·stăt): a device used to control the temperature in a heating system

thyroid (thī′roid): a ductless gland in the neck region which secretes a chemical important to body growth and mental ability

tissue (tĭsh′ū): a group of cells similar to each other in appearance and function

tourniquet (tŏŏr′nĭ·kĕt): any of several devices for checking bleeding from an artery by applying pressure

toxoid (tŏk′soid): a substance placed in the body to aid it in developing its own antitoxin

tractor (trăk′tẽr): a heavy duty automobile-like vehicle used for hauling, pulling heavy machinery, etc.

traditional (trȧ·dĭsh′ŭn·ăl): following a certain set style

transformer (trăns·fôr′mẽr): a device which changes the number of volts and amperes of an alternating current

translucent (trăns·lū′sĕnt): transmitting some light but diffusing it

transmission (trăns·mĭsh′ŭn): the gears taken together; the part of the automobile that transmits the power of the engine to the axle

transmitter (trăns·mĭt′ẽr): an instrument used to send telephone and telegraph messages

transparent (trăns·pâr′ĕnt): One is able to see through *transparent* objects.

transpiration (trăn′spĭ·rā′shŭn): the giving off of excess water by plants

tropism (trō′pĭz'm): the natural tendency of a simple living thing to move or turn in response to a stimulus

turbine (tûr′bĭn): a revolving blade machine using steam, water, or air as a means of applying force to do work

ultraviolet (ŭl′trȧ·vī′ō·lĕt) **rays** (rāz): the short invisible light rays from the sun

unit (ū′nĭt): a standard of measurement, as the foot, meter, liter, etc.

universe (ū′nĭ·vûrs): all matter and all space; all objects in space

uranium (ū·rā′nĭ·ŭm): one of the elements necessary to produce atomic energy

vaccine (văk′sēn): a fluid containing weakened or dead germs used in vaccination

vane (vān): a blade against which gas or water exerts pressure in a windmill or turbine

variation (vâr′ĭ·ā′shŭn): specific differences in qualities or characteristics in individuals of the same species

varnish (vär′nĭsh): a liquid made of either natural or synthetic resins dissolved in oils

vein (vān): the blood vessel through which blood returns to the heart

vertebrate (vûr′tē·brāt): an animal having a backbone

virus (vī′rŭs): a disease-producing protein chemical

vitamin (vī′tȧ·mĭn): one of the substances in foods necessary to health

volt (vōlt): the unit of measuring electromotive force

voltage (vōl′tĭj): the amount of pressure of an electric current

voluntary (vŏl′ŭn·tĕr′ĭ): controlled by the will

watt (wŏt): the unit measure of the power of electric current

wave (wāv) **length** (lĕngth): the distance from any one point in one wave to the corresponding point in the next wave

white (hwīt) **corpuscle** (kôr′pŭs·'l: a white cell in the blood that kills bacteria

work (wûrk): a force acting through a distance

X ray: a penetrating ray used in photographing the solid parts of the body through the flesh

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